AD NUMBER

AD160064

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; Mar 1958. Other requests shall be referred to Office of Naval Research, Arlington, VA 22217.

AUTHORITY

Office of Naval Research ltr dtd 28 Jul 1977

UNCLASSIFIED

Best Available Copy

AD 160064

Armed Services Technical Information Agency

ARLINGTON HALL STATION
ARLINGTON 12 VIRGINIA

FOR
MICRO-CA.
CONTROL ONLY

1 OF 4

UNCLASSIFIED

AD 160 064

Final Report

GEOMORPHOLOGY OF THE LAKE MICHIGAN SHORELINE

Project No. NR 2[illegible]-015
Contract No. Nonr-1228(07)

Northwestern University

Final Report

Geomorphology of the Lake Michigan Shoreline

By

William E. Powers

A Contract Between

Geography Branch, Earth Sciences Division
Office of Naval Research, Navy Department

and

Northwestern University

Project No. NR 387-015
Contract No. Nonr-1228(07)

William E. Powers, Director

Department of Geography
The College of Liberal Arts
Northwestern University
Evanston, Illinois

March, 1958

TABLE OF CONTENTS

LIST OF FIGURES (PHOTOGRAPHS)

Figure 11. B-4-Cb-r. Low wooded plain of lacustrine sand and gravel, with marginal belt 75-90 yards wide of foredunes 8-15 feet high. Nip 10 feet high. Beach of sand, coarse gravel, and angular shingle. Bedrock reef inferred. Physiographic Unit No. 305.

Figure 12. Dh-Cb. Wooded dunes in right distance 50-55 feet high. Belt 100-200 feet wide of foredunes 10-30 feet high, with low nip above broad sand beach. Small river on right lies back of foredunes. Physiographic Unit No. 334.

Figure 13. Dhb. Dunes 120-140 feet high; dune sand rests on 15 feet of lacustrine sand and gravel at base of bluff. Fresh bluff indicates recent active wave erosion. Narrow sandy beach. Physiographic Unit No. 594.

Figure 14. Dh-Cb. Wooded dunes at right 130 feet high. Foredunes (foreground) 15-20 feet high, with 6-8 foot nip. Beach zone of sand and gravel. Recent erosion is indicated. Physiographic Unit No. 594.

Figure 15. Dlb. Dunes about 35 feet high, with wave-eroded bluff 20-25 feet high. Broad beach of sand and fine gravel. Physiographic Unit. No. 607.

Figure 16. Dlb/B-4. Dunes 15-25 feet high rest on plain of lacustrine sand and gravel 12-14 feet above lake level. Fresh bluff on dunes shows wave erosion in recent years. Broad beach of sand and pebbles. Physiographic Unit No. 48.

Figure 17. Dl-r. Low wooded dunes (left background) with very broad beach mainly of sawdust and driftwood with about 20% sand. Rock reefs near water line defend beach at places. Physiographic Unit No. 329.

Figure 18. Dl-B-4. Gravel bar enclosing lagoon. At left beyond view is gravel foreland or plain in front of low dunes. Physiographic Unit No. 4[illegible].

Figure 19. Fh. Vertical cliff of dolomite 35-45 feet high. Narrow beach zone of angular slabs, blocks and shingle. Physiographic Unit No. 114.

Figure 20. Fh-B-4. Cliff of shaly dolomite and limestone, 30-35 feet high. At left is low gravel foreland 6-8 feet above lake. Beach is of angular shingle and slabs. Physiographic Unit No. 249.

Figure 21. Fl. Plain of dolomite about 18 feet above water, with vertical cliff 12-15 feet high. No beach zone. Physiographic Unit No. 149.

Figure 22. Fl-r. Plain of dolomite about 18 feet above water. Vertical cliff about 14 feet high. Narrow beach zone of cobbles and small boulders. Physiographic Unit No. 149.

Figure 23. B-4-r-M. Beach and offshore zone of low plain of lacustrine sand and gravel. Beach zone of sand, coarse gravel, and slabs. Reefs of dolomite show through beach deposits at places. Offshore zone 50-300 yards wide is filled with reeds. Physiographic Unit No. 396.

Figure 24. Ah-4. Margin of a plain of lacustrine sand and gravel 25-30 feet above lake. Road rests on fill stabilized by grass and protected at base from waves by riprap ridge. Physiographic Unit No. 235.

LIST OF TABLES

LIST OF APPENDICES

LIST OF PLATES AND SECTION MAPS

GEOMORPHOLOGY OF THE LAKE MICHIGAN SHORELINE

INTRODUCTION

The Project

Proposal. In October, 1955 William E. Powers proposed, with the endorsement of appropriate officers of Northwestern University, a project for studying the shoreline of Lake Michigan. This project, entitled "Lake Michigan Shore Erosion and Geomorphology Project," was submitted to the Office of Naval Research, U.S. Department of the Navy, with a request for equipment and funds to carry on field work for 2 summers, and office work, correspondence, research, and drafting necessary to prepare appropriate reports of progress, summary reports, and a final report on the findings of the study. The proposal was approved by the Office of Naval Research as Project No. NR 287-015, and in March 1957, Contract No. Nonr-1223(07) was negotiated between the Department of the Navy and Northwestern University to support the project for a period of one year beginning March 15, 1956. Preliminary studies and organizational work led to a successful program of field study during the summer of 1956. Early in 1957 the project was approved for extension during a second year as originally requested, and in April 1957 the Department of the Navy entered into such extension of Contract Nonr-1228(07) to March 14, 1958. A second summer of field work and a second year of office work, research, and preparation of reports was provided for.

Objectives. The proposal for this study stemmed from the need for more complete understanding of the characteristics and development of the shorelines of large inland lakes. Such shorelines present a large variety of shore features and conditions, which are of great influence on all aspects of man's use of the shore. In places the continuing processes of shoreline development -- such as the retreat or retrogradation of a bluff under wave erosion -- have

made it difficult and expensive for man to maintain his use of the shore areas. Both the kinds and associations of shore features on Lake Michigan, and their developmental processes, have their counterparts in other large inland lake shores. Thus governmental or military operations elsewhere can benefit by a clear understanding and description of Lake Michigan shore features. Individuals and municipalities who own shore properties are also in a position to benefit by the results of this study project.

Specifically, four objectives were set up:

1. To identify the diverse shoreline features of Lake Michigan, and to set up types and associations into which they may be grouped. To accomplish this, it was proposed to map, on foot or by automobile, the entire shoreline of Lake Michigan except (1) the Illinois shoreline (Lake and Cook Counties), and (2) the shoreline of Milwaukee County, Wisconsin. Both of these areas are comprehensively described in recent reports of the U.S. Army, Corps of Engineers.*

---

* Illinois Shore of Lake Michigan, Beach Erosion Control Study, by U.S. Army, Corps of Engineers: 83d Congress, 1st session, House Document No. 28, 1953.

Beach Erosion Study, Lake Michigan Shoreline of Milwaukee County, Wisconsin, by U.S. Army, Corps of Engineers: 79th Congress, 2nd Session, House of Representatives Document No. 526, 1946.

City of Kenosha, Wisconsin, Beach Erosion Control Study: 84th Contress, 2nd Session, House Document No. 273, 1955.

Other control studies on Lake Michigan by the U.S. Army, Corps of Engineers, are:

Racine County, Wisconsin, Beach Erosion Control Study: 83d Congress, 1st Session, House Document No. 88, 1955.

2. To appraise and measure shore developments now going on, including the total past changes due to such processes. More specifically, to identify shoreline areas of retrogradation and progradation; to measure if possible

the rate of such changes; and to determine whether such changes proceed at a uniform rate with respect to time, or occur in a non-uniform pattern related to cycles of lake levels, unusual storms, etc.

3. To summarize and present in appropriate reports information on shore features and processes, so that future changes can be anticipated.

4. To develop methods of applying the findings concerning the Lake Michigan shoreline to an understanding of the shores of large inland lakes in other parts of the world.

__Field Work__. Field studies were carried on by the director from June to September, 1956, and from June to August, 1957. During 1956 he was ably assisted by Mr. Harold A. Winters and Mr. John W. Kunstmann, graduate students in the Department of Geography, Northwestern University. In 1957, Mr. Winters alone served as field assistant.

During field work, the director and his assistants inspected the entire shoreline of Lake Michigan* at intervals of one mile or less, with few exceptions. Field mapping was done on areal photographs procured from the U.S. Department of Agriculture, Production and Marketing Division. These photos on a scale of approximately 1:20,000 served as photomaps; and in complete stereo coverage, they made possible the photointerpretation of the shoreline between points visited. All available topographic and planimetric maps of the shoreline were procured and made use of. Approximately 40 per cent of the shoreline is covered by topographic maps (Table I). For other areas, county maps giving the government Township and Range System and the road pattern were very useful, particularly by furnishing an interpretation of

* Hereafter in this report, the expression "Lake Michigan shoreline" will be understood to refer to the entire shore of the lake __exclusive__ of Milwaukee County, Wisconsin, and Lake and Cook Counties, Illinois.

the roads and fence lines on aerial photos with respect to Section and Township boundaries.

Table I. Published Topographic Maps of Lake Michigan Shore.

* = Advanced print subject to correction.

Wisconsin:

Quadrangle	Extent in Longitude	Extent in Latitude
Bayview	87°45' - 88°00'	42°45' - 43°00'
Casco	87°30' - 87°45'	44°30' - 44°45'
Cleveland	87°37'30" - 87°45'	43°52'30" - 44°00'
Green Bay	88°00' - 88°15'	44°30' - 44°45'
*Kewaunee	87°30' - 87°45'	44°15' - 44°30'
*Manitowoc	87°30' - 87°45'	44°00' - 44°15'
Milwaukee	87°45' - 88°00'	43°00' - 43°15'
New Franklin	87°45' - 88°00'	44°30' - 44°45'
Port Washington	87°45' - 88°00'	43°15' - 43°30'
*Sheboygan Falls	87°45' - 88°00'	43°30' - 43°45'
Sheboygan North	87°37'30" - 87°45'	43°45' - 43°52'30"
*Sheboygan South	87°37'30" - 87°45'	43°37'30" - 43°45'
Racine	87°45' - 88°00'	42°30' - 42°45'
Waukegan	87°45' - 88°00'	42°15' - 42°30'

Illinois

Quadrangle	Extent in Longitude	Extent in Latitude
Calumet Lake	87°30' - 87°37½'	41°37½' - 41°45'
Chicago Loop	87°37½' - 87°45'	41°52½' - 42°00'
Evanston	87°37½' - 87°45'	42°00' - 42°07½'
Highland Park	87°45' - 87°52½'	42°07½' - 42°15'
Jackson Park	87°30' - 87°37½'	41°45' - 41°52½'
Waukegan	87°45' - 88°00'	42°15' - 42°30'

Michigan		
Bangor	86°00' - 86°15'	42°15' - 42°30'
Benton Harbor	86°15' - 86°30'	42°00' - 42°15'
Central Lake	85°15' - 85°30'	45°00' - 45°15'
Charlevoix	85°15' - 85°30'	45°15' - 45°30'
Fennville	86°00' - 86°15'	42°30' - 42°45'
Holland	86°00' - 86°15'	42°45' - 43°00'
Lake Harbor	86°15' - 86°30'	43°00' - 43°15'
* Montague	86°15' - 86°30'	43°14' - 43°30'
Muskegon	86°00' - 86°15'	43°00' - 43°15'
South Haven	86°15' - 86°30'	42°15' - 42°30'
Three Oaks	86°30' - 86°45'	41°45' - 42°00'
Indiana		
Dunes Acres	87°00' - 87°07' 30"	41°37'30" - 41°45'
Michigan City West	86°52'30" - 87°00'	41°37'30" - 41°45'
Ogden Dunes	87°07'30" - 87°15'	41°37'30" - 41°45'
Porter	87°00' - 87°15'	41°30' - 41°45'
Three Oaks	86°30' - 86°45'	41°45' - 42°00'
Tolleston	87°15' - 87°30'	41°30' - 41°45'

The topographic maps in table I, listed clockwise around the Lake Michigan shore, starting at the Illinois-Wisconsin state boundary, are:

Wisconsin:
- Waukegan
- Racine
- Bayview
- Milwaukee
- Port Washington
- Sheboygan Falls
- Sheboygan South
- Sheboygan North
- Cleveland

Wisconsin: (continued)
Manitowoc
Kewaunee
Casco
New Franklin
Green Bay

Michigan:
Charlevoix
Central Lake
Montague
Lake Harbor
Muskegon
Holland
Fennville
Bangor
South Haven
Benton Harbor
Three Oaks

Indiana:
Three Oaks
Michigan City West
Dunes Acres
Ogden Dunes
Porter
Tolleston
Calumet Lake

Illinois:
Calumet Lake
Jackson Park
Chicago Loop
Evanston
Highland Park
Waukegan

The narrow width of most elements of the shoreline did not permit them, in general, to be mapped as areal units. Instead, a code was developed to permit an orderly description and summary of significant elements of the shoreline. This code will be described below. Detailed stratigraphic descriptions were made of exposed bluff and shore materials, and more than 700 samples of beach and bluff materials were collected. These will form the basis for a detailed description of the structure of many parts of the bluff and backland area, and a statistical study of the distribution of beach materials around the Lake Michigan basin.

Acknowledgments. The director is deeply appreciative of the support given to all phases of this project by the Office of Naval Research. In particular, he is indebted to Dr. Louis O. Quam, Head of the Geography Branch of the O.N.R., and to Mr. James A. Williams of the Chicago office of the O.N.R., who has been ever efficient and courteous in procuring necessary materials and in giving helpful advice on administrative problems. Messrs. Harold A. Winters and John W. Kunstmann served efficiently both as field assistants and as research and cartographic aids in the office.

Reports. To date, the following progress reports have been issued in mimeographed form:

1. Report of Progress No. 1, November, 1956.
2. Report of Progress No. 2, September, 1957.
3. Status Report, November, 1957.
4. Summary Report, November, 1957. AD-146 034

The present Final Report will present in scientific form the major findings on the geomorphology, detailed description, and classification of the shoreline features of Lake Michigan, as well as an analysis of shoreline changes at about 145 points selected for remeasurement. The mass of material collected cannot all be presented within a single report, and therefore it is anticipated that certain additional scientific studies will be made and, if given approval by the Office of Naval Research, will be submitted for publication to appropriate journals.

THE LAKE MICHIGAN BASIN

General Description

Lake Michigan is hydrologically a unit with Lake Huron, and constitutes the part of this great double water body which lies west of the Strait of Mackinac between Mackinaw City and St. Ignace, Michigan. The Lake Michigan basin is slightly curved in outline but is generally elongated in a north-south direction, with a curve toward the northeast at the northern part of the basin. The trend and curvature of the basin are rather closely adjusted to rock structure, the basin lying in a weak-rock belt of Devonian shale (see below). From the southernmost point at Gary, Indiana, to the northernmost point near Naubinway, Michigan, the length is about 315 miles. The maximum width is about 76 miles, in the latitude of Grand Haven and Milwaukee. Throughout most of its length the lake is 50 to 60 miles or more in width. The total area of water surface is nearly 22,450 square miles.

The greatest depth, 924 feet, occurs in the north-central part, approximately in the latitude of Kewaunee. A broad submerged ridge less than 240 feet deep crosses the basin in roughly the latitude of Milwaukee and Muskegon. The basin south of this ridge is 564 feet deep and constitutes the southern third of the lake.

The southern two-thirds of the Lake Michigan basin is marked by shores smoothly curved in plan, with no bays and almost no natural harbors suitable for large craft. Those harbors which have been developed here are mainly of two types: (1) small rivers dredged to float large vessels, as the Milwaukee, Chicago and Pike Rivers; and (2) elongated coastal lakes such as Muskegon Lake. Such lakes were once stream valleys eroded to a lower former level of Lake Michigan, then drowned and partly cut off by sand bars as the Lake Michigan level rose. It has been shown by Hough that Lake Michigan's predecessor,

called Lake Chippewa, stood 360 feet lower than the present level.*

---

* Hough, J.L., Pleistocene Chronology of the Great Lakes Region: Final Report, Office of Naval Research -- University of Illinois Project NR-018-122, Urbana, Illinois, 1953.

Hough, J.L., Geologic History of Great Lakes Beaches: Proceedings, Fourth Conference on Coastal Engineering, Countil on Wave Research, University of California, Berkeley, 1954, pp. 79-100.

Three large embayments are present in the northern part of the Lake Michigan basin. Green Bay on the northwest is about 15 by 116 miles in size. It lies parallel to Lake Michigan and separated from the latter by dolomite peninsulas called the Door and Garden Peninsulas, respectively (see Plate I). At the north, Green Bay is divided by a second peninsula — the Stonington — into two parts, Big Bay de Noc on the east and Little Bay de Noc on the west. Between Garden and Door Peninsulas the dolomite ridge or cuesta is partly submerged and gives access to Green Bay between several rocky islands. On the east of Lake Michigan, Little Traverse Bay trends east-west, with a length of about ten miles. South of it, Grand Traverse Bay forms an indentation about 10 by 30 miles in size, trending south from its entrance at the north. A narrow peninsula, Old Mission Point, divides the bay for more than half its length. The east and west arms of Grand Traverse Bay were parallel to glacial advance during at least part of the Ice Age, and were deeply scoured. A depth of 534 feet in the eastern arm, and 390 feet in the western arm, have been measured.

Several islands occur in the northeastern quarter of Lake Michigan, but none is present farther south.

Drainage

A surrounding land area of more than 47,000 square miles drains to Lake Michigan. The divide bounding this drainage area lies more than 115 miles from the Lake Michigan shore east of South Haven, Michigan; and less than 5 miles from the shore between Waukegan, Illinois, and the Wisconsin-Illinois boundary. In an arc extending from the Indiana-Michigan boundary around southern Lake Michigan and northward to Port Washington, Wisconsin, the divide is everywhere less than 20 miles from the lake shore. Throughout much of this distance the divide follows the crest of the Valparaiso glacial moraine. The divide lies about 100 miles northwest of Green Bay.

No major river flows into Lake Michigan. The principal streams now or formerly entering the lake are as follows, clockwise beginning at the south:

In Indiana:

- Trail Creek (at Michigan City)
- Grand Calumet River (at Gary, formerly Miller)

In Illinois

- Chicago River
- Waukegan River

In Wisconsin:

- Pike River (at Kenosha)
- Root River (at Racine)
- Milwaukee River
- Sucker Creek (near Port Washington)
- Sheboygan River
- Pigeon River (at Sheboygan)
- Manitowoc River
- East and West Twin Rivers (at Two Rivers)
- Kewaunee River
- Ahnapee River (at Algoma)
- Fox River (at Green Bay)
- Duck Creek (at Green Bay)
- Pensaukee River
- Oconto River
- Peshtigo River
- Menominee River (Wisconsin-Michigan boundary)

In northern Michigan:

- Cedar River
- Ford River
- Escanaba River
- Rapid River
- Whitefish River
- Sturgeon River

In northern Michigan (continued)
- Fishdam River
- Manistique River

In southern Michigan:
- Betsie River
- Manistee River
- Big Sable River
- Lincoln River
- Pere Marquette River (at Ludington)
- Pentwater River
- White River
- Muskegon River
- Grand River (at Grand Haven)
- Black River (Macatawa Lake)
- Kalamazoo River
- Black River (at South Haven)
- Pawpaw River (at St. Joseph)
- St. Joseph River
- Galien River

Of these, the Chicago River was reversed in 1900 by the Chicago Sanitary District development and now taken water from Lake Michigan; while the Grand Calumet River's mouth at Gary has long been closed, the river discharging through Burns Ditch, an artificial cut east of Gary, and the Lake Calumet harbor canal, in south Chicago. Only eight streams have an average discharge into Lake Michigan of more than 1000 cubic feet per second. These are

	$Ft.^3$ /sec.
Fox River	4,317
Menominee River	3,202
Grand River	3,080
St. Joseph River	2,791
Manistique River	1,747
Muskegon River	1,726
Kalamazoo River	1,236
Manistee River	1,088

Most streams entering Lake Michigan have their maximum flow between March and June, due to melting of winter snow and to a general maximum of precipitation at that season in this region. A considerable variation occurs in stream flow, the maximum recorded flows exceeding the average by factors ranging from 4.7 to 11 in the larger streams and from 3.2 to 38 in the smaller

ones. The maximum flow exceeds the minimum by factors of from 24 to 154 in the larger streams, and from 52 to more than 1000 in the smaller.

The amount of sediment now being carried into Lake Michigan by tributary streams is small in comparison with sediments eroded from bluffs of unconsolidated materials by wave action. The prevalence of abrupt bluffs or cliffs along a large portion of the shoreline (see Section Maps 1 to 26, and text below) is indication that such shores are retreating under wave attack. Deltas, which indicate a substantial contribution of sediment by the streams that build them, are generally absent except on the west side of Green Bay. Here the Oconto, Peshtigo and Menominee Rivers have built small deltas, each indicated by a projecting point of land at the mouth of the stream.

Relief

Lake Michigan is surrounded by plains of relatively low relief, that originated mainly as glacial till plains or as lacustrine plains submerged by former higher stages of the lake during retreat of the continental glacier. In places these plains rise gently with increasing distance from the present shore, as on the west side of Green Bay. In other places the adjoining land was originally higher, and wave erosion has developed steep bluffs ranging in height from ten or twenty feet to as much as 540 feet (at Sleeping Bear point in Leelanau County, Michigan). Such bluffs commonly slope from 20 to 35 degrees to the horizontal. At places sand dunes have developed along the shore and form a belt of varying width, but commonly less than one mile wide. These dunes range in height from a few feet to more than 200. Their slopes range from a few degrees to more than 35 degrees. Such dune belts are most common on the north, east and south shores of the lake, and are generally associated with areas of lake plain inland. Bedrock occurs at or just above lake level

at many points on the north coast, but bedrock areas inland generally rise only a few feet or tens of feet above the lake. A few exceptions occur where bedrock makes an upland from 50 to 200 feet or more above lake level, with a steep or vertical rock cliff formed by wave action. Notable examples are parts of the west shore of Door Peninsula, Wisconsin, and Garden and Stonington Peninsulas, Michigan.

Inland from the shore, relief remains small and all parts of the drainage area tributary to Lake Michigan may be classed as rolling to flat plain.

Coastal Landform Types

An inventory of landforms along the Lake Michigan coast indicated that the following major types are present:

A. Upland with bluff facing lake. Categories of upland as to origin or structure include:
   1. Glacial till plain
   2. Glacial sand and gravel outwash plain
   3. Dune sand plain
   4. Lacustrine plain, or sand and gravel
   5. Lacustrine plain of silt and clay

B. Low plain without bluff. Categories as to origin and structure include:
   1-5. Same as under upland
   6. Stream alluvial plain or delta
   7. Swamp
   8. Bedrock plain.

C. Foredune belt; i.e., low dunes not more than a few decades old, lacking large trees or forest. Some foredune areas are marked by a low nip or bluff marking recent erosion by waves.

D. Old dunes, generally higher than foredunes and partly or wholly fixed by forest and other vegetation. Some old dune areas are marked by wave-eroded bluffs facing beach.

E. Sand bar or spit. Several long lakes emptying into the eastern side of Lake Michigan were originally river valleys eroded to a lower level of the lake, but are now drowned by rise of lake level and are partly cut off by bars or spits built by wave action. On some of these bars and spits, sand dunes have been built.

F. Bedrock upland with cliff. The fact that such rocky cliffs are generally far steeper than bluffs in unconsolidated materials indicated that they belong in a different category from the bluffs and uplands of type A above.

M. Reed marsh coast. This type, in contrast to types A to F above, generally has no beach associated with it. Type M always associated with one or the other basic types of shore.

R. Artificial fill, placed by man to control shore erosion or to support a highway or some other man-made structure.

For purposes of field mapping, a code was developed to indicate the above landform types and their combinations, together with minor subdivisions of and additions to them. This code and its use will be explained below. It will be noted that types A, B, D and F indicate the character of the backland area. Bluffs and cliffs generally display excellent cross sections of the geological materials and structure of the backland.

Geological Setting of the Lake Michigan Basin

Underwater Conditions. The lake basin consists of two depressions separated by a broad submerged swell between Muskegon and Milwaukee. The southern basin slopes gently inward from all sides to its deepest point of 564 feet. The submerged ridge is less than 240 feet deep at several places. It probably is the submerged terminal moraine of the Valders glacial lobe, whose red drift marks the last major glacial advance down the Lake Michigan basin into eastern Wisconsin. The larger northern depression is irregular in form, with generally steeper submerged slopes on the east side than on the west. The maximum depth of 924 feet lies almost due east of Kewaunee. Underwater contours suggest that its eastern margin may be a drift-mantled westward-facing cuesta similar to that forming the west side of the Door Peninsula. The northeastern part of the basin is very irregular in form. Most of the islands stand like tablelands with steeply sloping margins, rising

from depths of 250 to 300 feet. Several submerged platforms would form islands if water level should drop 50 to 100 feet. Grand Traverse Bay is a double submerged valley almost fiord-like in form. The two arms have depths of 390 and 534 feet in the south, although the northern entrance to the bay is a threshold only 138 feet deep. Extending eastward through the Strait of Mackinac is a narrow submerged gorge known to be more than 150 feet deep. This probably was the outlet valley for the former lake stage (Lake Chippewa) when the water stood 350 feet lower than at present. Green Bay is generally shallow, largely less than 100 feet deep, and appears to be an elevated platform overhanging the deeper Lake Michigan basin on the east.

Exposed Bedrock Geology. Although bedrock exposures are limited along most of the Lake Michigan shoreline, the lake basin nevertheless is clearly related in form and trend to the regional bedrock and stru cture. From an outcrop on the beach near 79th street in Chicago no bedrock is exposed around the south end of the lake and northward past Grand Traverse Bay to near Norwood in Charlevoix County, Michigan, where a low cliff of shale is present. Frequent rock outcrops occur between Norwood and Petoskey, and from Mackinaw City west to Waugoshance Point, Michigan. North of the lake, bedrock forms many reefs, ledges, and low points from St. Ignace westward to the Garden and Stonington Peninsulas. Door Peninsula is a rocky cuesta, high on the west. South of it, the only bedrock exposures on the west side of Lake Michigan are near Algoma, at Sheboygan, north of Racine (Wind Point), and probably in the water off Glencoe, Illinois.

Rock formations underlying Lake Michigan or its shores range in age from Ordovician to Mississippian, with the Silurian and Devonian systems also represented. It is difficult to draw up generalized stratigraphic sections for

the states of Wisconsin, Michigan, Illinois and Indiana, partly because local names and degree of differentiation vary, but also because stratigraphy varies and correlations are not agreed upon for many units. The following description, given in order of age, suggests stratigraphic relations that appear to hold generally throughout the area.

Ordovician. The Trenton-Black River (mainly limestones) of Michigan correlate with the Galena-Black River dolomites of Wisconsin and Illinois. These are resistant units and lie northwest of Green Bay. The Maquoketa shale of Illinois correlates with the Richmond shale of Wisconsin, which underlies southern Green Bay. This time interval is represented in northern Michigan by the Queenston Shale, Big Hill limestone, Stonington limestone and Bills Creek Shale. The resistant Stonington makes the peninsula of that name, while the Bills Creek shale forms Little Bay de Noc lowland. Queenstown shale underlies western Big Bay de Noc.

Silurian. The massive Niagaran dolomite of Wisconsin and Illinois forms the Door Peninsula cuesta. Its correlatives in northern Michigan are the Guelph (youngest), Engadine and Manistique dolomites, Burnt Bluff limestone, Mayville dolomite, Cabot Head shale, and Manitoulin limestone. The Garden Peninsula cuesta appears to be formed of the Manistique, while the Engadine forms reefs and low ledges along much of the north shore of Lake Michigan.

The Salina series (salt, limestone, shale, dolomite, and gypsum) of upper Silurian age forms a weak rock belt containing Brevort Lake, northwest of St. Ignace.

Devonian. The Lake Michigan basin is eroded largely in Devonian rocks. At the south, in Indiana, the rock units are the New Albany shale (youngest Devonian present), Beechwood and Silver Creek limestones, and Jeffersonville

shale. At the north, the Straits of Mackinac area is underlain by the Devonian Onandaga series, including the Mackinac and Dundee limestones. South of the Straits area, extending as far as Frankfort, the younger Devonian Traverse series underlies the coast and the eastern part of the Lake Michigan basin. The Traverse series includes, where differentiated, the Thunder Bay, Alpena and Long Lake limestones, and the Bell shale.

Mississippian. The coast and eastern part of the Lake Michigan basin south of Frankfort are underlain by rocks of the Mississippian system. The formations which reach the coast or basin are the Antrim shale (oldest), Coldwater shale, and lower Marshall sandstone. Younger, higher stratigraphically Mississippian formations are found inland, toward the east.

Unconsolidated mantle. The bedrock formations enumerated above are almost wholly covered, except on the northern and northwestern shore areas of Lake Michigan, by glacial deposits of till, gravel and sand; by glaciolacustrine deposits of sand, gravel, silt and clay; by eolian deposits of dune sand; or by marsh vegetation and muck.

Geological Structure. Lake Michigan lies on the west and northwest flanks of a shallow basin structure in sedimentary rocks, centered in southern Michigan. In the central and southern parts of Lake Michigan, the associated sedimentary bedrock formations dip or slope down toward the east at an angle of 100 feet or less per mile. The northern Lake Michigan basin lies northwest of the center of the structural basin, so that the dip is there to the southeast, at 50 to 100 feet per mile. The curved basin of Lake Michigan thus follows closely the curved outcrop of the weaker rock formations mainly of Devonian age, and may be said to lie in a "strike valley." The term "strike" means the direction at right angles or normal to the direction of rock dip.

Relation of Lake Michigan Basin to Moraines. Most if not all the glacial drift in and adjacent to the Lake Michigan basin appears to have been dropped by glacial lobes that advanced down the basin lowland from the northeast, and then spread outward from the center of the basin onto the surrounding higher plains. Marginal moraines therefore trend roughly parallel to the present shoreline. However, later glacial advances did not reach quite as far south as earlier ones.

South of Milwaukee and Muskegon, the glacial moraines at and near the shore belong to the Lake Border morainic system built during the Cary glacial substage of the last or Wisconsin glacial stage. Inland from (or outside of) the several Lake Border moraines are older moraines called in Illinois the Tinley and Valparaiso, also deposited during the Cary substage. Tinley or Valparaiso drift may occur beneath Lake Border drift, where exposed in bluffs along the shore. North of Milwaukee and Muskegon, red drift called Valders in Wisconsin and Manistee in Michigan forms the moraines along the shore. This drift is of the Mankato substage of the Wisconsin glacial stage, the glacial lobe of which reached only as far as the two cities mentioned. However, it is known that a Cary glacial lobe — called the Port Huron — later than the Lake Border, advanced into the northern Lake Michigan basin before Mankato time.* Therefore, it is to be expected that the red Valders-Manistee drift

---

* Bretz, J.H., The stages of Lake Chicago: Their causes and correlations: American Journal of Science, vol. 249, 1951, pp. 401-429.

---

may be underlain by deposits of Port Huron, Lake Border, or even older glacial age. Sections of glacial drift exposed in bluffs in the northern part of the basin generally show several drift sheets which attest the successive glacial advances and retreats.

PHYSIOGRAPHIC UNITS OF THE LAKE MICHIGAN SHORE

Physical Elements of the Shore Zone

Definitions. The shore zone is commonly divided into the offshore, the shore, the landface, and the backland. The offshore extends seaward from the low water mark (or waterline, in the case of lakes with slight fluctuations in water level). The shore is the zone between low water mark and the highest limit reached by waves or ice shove. The landface is a zone extending landward from upper limit of shore, to limit of direct influence of shore processes. The backland is a zone extending indefinitely landward from the inner limit of landface. The shoreline is technically the boundary between offshore and beach; and in practice this means the outer limit of the shore, or the low water line. The coast is a zone of indeterminate width extending landward from the shore; it therefore includes the landface and backland. The coast-line is the boundary between shore and landface. The term shore zone refers to the combined offshore, shore, and landface.

The present study deals with the shore, landface, and outer margin of backland. The shore at most places includes a beach, generally of sand but in some cases composed of gravel, cobbles, boulders or other loose materials. The beach is commonly subdivided into the foreshore or lower beach, reached by ordinary storm waves; and the backshore or upper beach, reached by waves only during exceptional storms, and perhaps reached by ice-shove during winter freezes.

The landface may be a cliff, a bluff, a nip, or a gentle slope marking the outer edge of backland. A cliff is a steep or vertical slope in rock. Cliffs overlooking and near to the Lake Michigan shore were developed by wave erosion at their base. The term bluff refers to a sharp slope in

unconsolidated material such as glacial till or dune sand. Such materials, when eroded below by wave action along the shore, tend to slide down until they attain their angle of repose for the conditions present. Old bluffs in glacial till commonly are no steeper than 25°, but where recently undermined by wave action, bluffs in till may attain slopes of 40° to 50° or more. Loose dune sand makes bluffs at its angle of repose, generally about 32°. A recently formed low bluff only a few feet high is often called a nip. Low plains not subject to recent wave erosion may have merely a gentle slope down to the beach as a result of former wave work. Such a declivity is not a true nip or bluff.

Elements Present. The elements composing the Lake Michigan coast and shore have been in part enumerated under Coastal Landform Types. In terms of the nomenclature of shore zones, these elements include the following:

Backland:
- a. Uplands of several types of unconsolidated deposits, or of bedrock
- b. Low plains of the same materials
- c. Foredune areas
- d. Old dune areas
- e. Artificial fill

Shore:
- a. Foreshore zone
- b. Backshore zone
- c. Rock reefs or ledges in shore
- d. Sand bar or spit
- e. Reed marsh coast, generally without a true beach

Landface:
- a. Bluff or nip
- b. Cliff

A Code for Mapping Elements of the Shore Zone

Test mapping procedures resulted in a workable code system for setting down all significant elements of the shore zone, except descriptions of the foreshore and backshore. Because a beach zone, with foreshore and backshore, generally occurs along with all types of landface, it was believed that the addition of coded information on beaches to the code for the backface would

prove cumbersome to the user of the report. Therefore, the code deals only with the backland, landface, and such unusual features of the shore as rock reefs or marsh.

The mapping code is as follows:

A. Upland with bluff.
   Ah — high bluff, more than 20 feet high.
   Al — low bluff, less than 20 feet high.
      Materials of bluff and backland:
         1. Glacial till
         2. Glacial sand and gravel
         3. Dune sand
         4. Lacustrine sand and gravel
         5. Lacustrine silt or clay
      Examples: Ah-1, high upland of till, with bluff.
         Al-1/4, low upland of till over lacustrine sand and gravel, with bluff.

B. Low plain, generally without nip.
      Materials of plain:
         1 to 5. Same as above
         6. Stream alluvium, mainly gravel, sand mud and silt
         7. Swamp
         8. Bedrock
      If rock ledge or reef occurs in beach zone, r is added.
      Example: B-2-r, low plain of glacial sand and gravel, with reef on beach.

C. Foredunes, mostly less than 20 feet high.
   Cb, if low bluff or nip is present.
   C, if no bluff or nip is present.

D. Old dunes, generally wooded and mostly more than 20 feet high.
   Dh — high dunes, more than 40 feet high.
   Dl — low dunes, less than 40 feet high.
      If bluff is present b is added.
      Example: Dlb, low dunes with bluff.

E. Sand bar or spit.
      If dunes are on top, d is added.
   Example: Ed, spit or bar with dunes.

F. Bedrock upland with cliff.
   Fh — high cliff, more than 20 feet high.
   Fl — low cliff, less than 20 feet high.

M. Reed marsh in offshore or foreshore. Generally no beach is present. This type occurs with other basic types of coastal features.
Example: B-4-M: Low plain of lacustrine sand and gravel, with reed marsh offshore.

R. Artificial fill. This generally occurs with some other basic types of coastal features.
Example: A1-2-R, upland of glacial sand and gravel with bluff less than 20 feet high, with artificial fill along "shore."

All coastal features of Lake Michigan, in their various combinations and associations, were mapped by use of the code described above. In field notes, detailed descriptions were taken of (a) the shore, including width and materials of the foreshore and backshore; (b) the height, angle of slope, materials and structure of the landface (i.e., bluff or cliff); nature of backland area; (c) the stability of shore and landface, specifically whether stable, retrograding under shore erosion, or prograding under processes of deposition; (d) evidence, if any, for direction of longshore current. Many bluffs showed detailed stratigraphy involving several units of glacial till, glacial or lacustrine sand, gravel, silt or clay -- and these sections were recorded and described in detail. They will form the basis for an analysis of the glacial stratigraphy of the Lake Michigan area. Samples of beach sands from the foreshore and backshore, and of the materials composing the adjacent bluffs or backland, were collected at 184 selected stations, to a total of 704 samples.

Associations of Coastal Features of Lake Michigan

Along the thousand miles and more of Lake Michigan's shore zone, the coded elements as listed above are found in a variety of combinations. An enumeration of some of these indicates how necessary it was to develop a code or symbolism to record the elements associated at each station studied.

High Bluff. Characteristic associations are:

Ah — High bluff alone.
Ahr — High bluff with rock reef on shore below.
Ah-B — High bluff above low plain.
Ah-C — High bluff with foredunes at base. If dunes have nip or bluff, Ah-Cb.
Ah-Al— High bluff, back of low bluff.
Ah-Dl —High bluff with low dunes at base. These dunes may have their own bluff, Ah-Dhb, or may have foredunes adjacent to beach: Ah-Dh-C or Ah-Dh-Cb.

Low Bluff. Characteristic associations are:

Al — Low bluff alone.
Al-B — Low bluff above low plain. If rock reef on beach, Al-B. Or if reed marsh in offshore, Al-B-M.
Al-C — Low bluff with foredunes at base. If nip in dunes, Al-Cb.
Al-M — Low bluff with reed marsh in offshore.
Al-Al — Two low bluffs, one back of the other.
Al-Ah — Low bluff above and back of high bluff.

Low Plain. Characteristic associations are:

B — Low plain alone. If rock reef on beach, B-r.
B-M -- Low plain with reed marsh in offshore.
B-C — Low plain with foredune belt. If nip in dunes, B-Cb.
B-E — Low plain with marginal sand bar or spit. If foredunes on plain, B-C-E.

Foredunes. These always are associated with other elements of land-face or backland, and are therefore included with the latter.

High Old Dunes. Characteristic associations are:

Dh — High dunes alone.
Ch-C — High dunes with lower foredune belt. If nip in foredunes, Dh-Cb.
Dh-Dl — High dunes back of low old dunes. If bluff in latter Dh-Dlb. If foredunes also occur, Dh-Dl-C or Dh-Dl-Cb.
Dh-B — High dunes on low plain. If foredunes near lake, Dh-B-C or Dh-B-Cb.
Dh/Ah — High dunes on upland with high bluff. If foredunes at base, Dh/Ah-C or Dh/ah/cb.
Dhb — High dunes with eroded bluff. If foredune belt is present, Dhb-C or Dhb-Cb.
Dhb/Al— High dunes with old bluff on upland with low bluff.
Dhb-B -- High dunes with old bluff on low plain.

Low Old Dunes. Characteristic associations are:

Dl — Low old dunes alone. If rock reef on beach, Dl-r.
Dl-C — Low old dunes with foredunes. If nip, Dl-Cb.
Cl-B — Low dunes on low plain. If foredunes also, Dl-B-C.
Dl/Al — Low dunes on upland with low bluff.
Dl/Ah — Low dunes on upland with high bluff.
Dlb — Low dunes with bluff. These may occur on low plain, Dlb-B; or on spit or bar, Dlb-E.
Dlb-C — Low dunes with bluff, above foredune belt.

Spit or Bar. The most common association is with foredunes, E-C or E-Cb; or with old low dunes, E-Dl or EDlb.

High Bedrock Cliff. Characteristic associations are:

Fh — High cliff alone. If reefs on beach, Fh-r. If reed marsh in offshore, Fh-M.
Fh-B — High rock cliff back of low plain.
Fh-Al — High rock cliff above upland with low bluff.

Low Bedrock Cliff. Characteristic associations are similar to those of high bedrock cliff.

Description of Lake Michigan Shore Zone in Terms of Physiographic Units

The shore zone of Lake Michigan varies significantly from place to place. Detailed mapping of the shore zone elements indicates that more than 600 distinct physiographic units are present, each distinct from those adjacent to it. These physiographic units are shown on Section Maps, Numbers 1 to 26. The locations of these section maps are indicated on Plate I. In addition to the physiographic units of the shorezone, these section maps give also the code mapping symbols for nearly 1700 shore stations, and a smaller number of symbols indicating graphically the general character of the coast (whether high bluff, low dune, cliff, etc.) and the height of bluffs, dunes, and cliffs composing the landface of backland. See Appendix I, page 102, which is an explanation of these symbols used on the 26 Section Maps. Appendix II, page 103, is a copy of the code used in field mapping, which

explains the letter and graphic symbols used on the Section Maps.

Below is a table listing the basic elements by symbols, and basic information on the landface and shore, for the more than 600 physiographic units. The following abbreviations are used for the beach sediments:

s	—	sand
fn	—	fine
cs	—	coarse
med	—	medium
gr	—	gravel
cobs	—	cobbles
bldrs	—	boulders

Table II. Physiographic Units of the Lake Michigan Shore Zone.

Physiographic unit number	Basic coast zone elements	Height (ft.) bluff, cliff or dunes	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
1	B-4	---	---	0-54 S, 98% med gr	0-77 S, 75-98% med gr	Figure 8
2	Al-4	8	40	14 S, 50% cs gr	33 S, 10% cs gr	
3	Ah-3/4	30	35-90	0-10 S, 30% cs gr	14 gr cobs	
4	Al-4	10-18	30-50	none	0-15 S gr blks	
5	R	---	---	---		
6	Al-4-B-4	35 above plain	20	33 S, 70% med gr	18 S med gr	
7	Ah-4/1	38	30-70	0-10 S, 95% fn gr	16-43 S, 40% med gr	
8	R	15-25	50-90	none	none	
9	Al-4/1 Al-1	12-14	10-90	39-75 S, 98% fn gr	33 S, 97% fn gr	
10	Ah-1 Ah-4/5 Ah-4/5/1	30-50	35-60	0-27 S, 35-97% med gr cs gr	0-55 S, 25-95% cs gr cobs	
11.	Ah-5/1-B-R	35-45 above plain	30	none	none	
12	Ah-4/1 Ah-1 Ah-5/1	18-55	35-70	0-25 S, 99% fn gr clay	0-47 S, 99% fn gr	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dunes	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
13	Ah-5/1-Al-5-r	15/10	30-45	10 S, 60% cs gr	15 S, 80% med gr cobs	
14	B-4-r	—	—	30-38 S, 50-92% cs gr	20-27 S, 50-85% med gr	
15	Ah-1 Ah-5/1 Ah-4/5/1	27-100	35-90	0-90 S, 92-99% fn gr	10-37 S, 40-98% med gr	
16	Ah-1	75-100	35	Narrow shore zone		
17	Ah-1-Al-4	100/10-20	30/45	3-10 S, 95% fn gr	22 S, 95% fn gr	
18	Ah-1 Ah-1-4-5/1 Ah-1/5/1	75-150	26-90	0-25 S,25-97% med gr cs gr	6-42 S, 20-98% fn gr, cs gr cobs, bldrs	
19	Ah-Al-4	15-20	30	15 S, 40% cs gr cobs	12 S, 20% fn gr cobs bldrs	
20	Ah-1	50-90	30-35	6-25 S, 25-50% med gr cs gr	22-25 S, 40-99% cs gr bldrs	
21	Al-4 Al-4-r	4-15	30	0-20 S, 25% cs gr	0-25 S, 25% cs gr cobs	
22	B-4-r	—	—	10 S, 25% cs gr	20 S, 70% cs gr, cobs bldrs	
23	Al-4-r	15	10-15	13 S, 10% cs gr	20-25 S, 96% bldrs	

Physiographic unit number	Basic Coast zone elements	Height (ft.) bluff, cliff or dunes	Slope in degrees, bluff or cliff	Backshore: Width in ft.; materials	Foreshore: width in ft.; materials	Photo number
24	B-4	——	——	11 S, 90% med gr	25 S, 94% fn gr	
25	A1-4	12	30	18 S, 92% med gr	40 S, 97% fn gr	
25A	B-4 B-4-r	——	——	25-30 S, 99% [illegible] gr	50-55 S	
26	B-4 B-4C	——	——	[illegible]-27 S, 99% fn gr	17-37 S bldrs	
27	B -4-Cb	——	——	35-60 S	37-55 S	
28	B-4-C B -4	——	——	0-53 S	35-67 S	
29	B-4-Cb	——	——	0-27 S	0-35 S	
30	D1-Cb	35-45 15-25	35	20-30 S, 99% fn gr	27-40 S, 96-99% fn gr	
31	D1b D1-C	15-35 3-6	30-35	17-25 S, 93-99% fn gr cs gr	30-35 S, 96-99% fn gr cs gr	
32	Ah-4 Ah-1 A1-5	10-50	35-60	0-32 S	0-55 S	
33	B-4	——	——	35 S	100 S	
34	R	——	——	none	none, Riprap	
35	Ah-4	15-18 plus	35	40 S	35 S	
36	Ah-4-r	30	35-40	none	none	

Physio-graphic unit number	Basic coast zone elements	Height (ft.) bluff cliff or dunes	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
37	Ah-5/1 Ah-4/1 Ah-1/4/5/1	35-60	35-60	0-15 S, 95-98% med gr cs gr	5-27 S, 5-98% cs gr, cobs bldrs	
38	Ah-5-B-4	15-25 above plain	30	12 S, 92% med gr	22 S, 95% med gr	
39	Ah-4/1 Ah-5/4 Ah-1/4/5/1	18-80	20-60	0-20 S, 90-99% fn gr, med gr bldrs	11-40 S, 20-99% fn gr, cs gr	
40	Al-1-B-4-R Al-4-B-4	15 above plain	30	8-17 S	40-45 S	
41	Ah-1-Al-5	30/15	40/30	none	0-35 S	
42	Al-4 Al-5 Al-1	9-18	15-50	0-22 S, 95-99% cs gr	15-40 S, 0-98% med gr, cs gr bldrs	Figure 4 Figure 5
43	B-4	—	—	7-32 S	32-37 S	
44	B-4-Cb	5-10	—	20 S	37 S	
45	Dl-C Dl-Cb	10-45/5-15	35-40	10-63 S	47-75 S	
46	Dlb	20	30	10 S, 97% fn gr	27 S, 98% med gr	
47	Dl/B-4	10 above plain	—	10 S, 97% cs gr	37 S, 92% fn gr, cs gr	
48	Dlb Dl/B-4	15-30	30-40	17-25 S, 99% cs gr	35-40 S, 96-98% fn gr, cs gr	Figure 16

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dunes	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
49	Al-4 Al-4/1	5-16	45-50	3-5 S, 95-97% med gr, cs gr	21 S, 80-99% med gr, cs gr	
50	B-4	—	—	15 S	16 S, 99% fn gr	
51	Al-1	15	50	6 S, 99% cs gr	20 S, 98% fn gr, med gr	
52	Ah-1/5/1 Ah-1/4 Ah-1-Ah-4/1 Al-1	12-95	35-90	0-33 S, 85-100% cs gr, med gr clay	0-32 S, 50-99% fn gr, med gr cobs, bldrs	
53	B-4	—	—	30 S	45 S	
54	Ah-1/4/1 Ah-1/5/1 Ah-1	55-70	35-90	0-15 S, 55-94% med gr cs gr	8-35 S, 60-96% med gr, cs gr bldrs	Figure 1
55	Ah-1-Al-1	45/9	35/40	10 S, 88% med gr	35 S, 95% cs gr	
56	Ah-1 Ah-1/4 Ah-1/4/1	55-70	35-90	0-15 S, 40-93% cs gr cobs	12-30 S, 65-99% fn gr, med gr cs gr, bldrs	
57	Al-1	9-18	35-50	4-6 S, 30-50% med gr, cs gr bldrs	16-18 med gr cs gr bldrs	
58	Ah-1-B-1 Ah-1-B-4	30-35 above plain	30-35	8-12 S, 80-92% med gr, cs gr	25 S, 10-25% med gr, cs gr	
59	Ah-1	70	40	6 gr, bldrs	23 S, 60% gr, bldrs	

Physio-graphic unit number	Basic coast zone element	Height(ft.) bluff, cliff or dunes	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
60	Al-4	17-20	25-40	15-22 S	21-35 S, 88-99% fn gr	
61	Ah-1 Ah-1/4	55-70	35-90	0-8 S, 25-70% cs gr, bldrs	12-18 S, 25-65% med gr, cs gr bldrs	
62	Ah-1/4-Al-4	50/11	35/35	8 S, 90% cs gr	20 S, 80% med gr, cs gr bldrs	
63	B-4 Ah-1-B-4/1	30 above plain	20-35	5-10 S, 25-90% cs gr	16-30 S, 25-96% cs gr	
64	Al-4	10-15	30-55	10-15 S, 70-99% cs gr	22-35 S, 92-100% cs gr, bldrs	
65	Al-4-r	10	35	9 cs gr	45 S, 95% cs gr	
66	Ah-1-Al-4	55/22	40/30	6-8 cs gr	21 S, 60% cs gr, bldrs	
67	Ah-1	55	35	Narrow gravelly beach zone		
68	B-4 Al-4	5-8 where Al-4	15-35 where Al-4	0-39 S, 50-95% med gr, cs gr bldrs	17-42 S, 60-100% fn gr, med gr cobs, bldrs	
69	B-4-r	---	---	12-22 S, 0-90% fn gr, cobs bldrs	10-33 S, 0-80% cs gr, cobs bldrs	Figure 10
70	B-4-C B-4-Dlb	15 Dlb	30 where Dlb	33-51 S, 98-100% fn gr	22-49 S, 99% fn gr	

Physio-graphic unit number	Basic coast zone element	Height(ft.) bluff, cliff or dunes	Slope in degrees bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
71	B-4-r	---	---	50 S, 93% fn gr	60 S, 20% cs gr, cobs slabs	
72	B-4 B-4-C B-4-D1 A1-4	3-10 where A1, B-4-C	30 where A1	10-39 S, 85-99% med gr	16-45 S, 85-99% fn gr, med gr cs gr	
73	B-4-C B-4-Cb	3-12 where C	---	24-34 S, 95-99% fn gr	29-40 S, 99% fn gr	
74	D1-C D1-Cb	2-10	35	34-73 S, 95% fn gr	27-52 S, 95% fn gr	
75	B-4-r	---	---	narrow gravelly shore		
76	B-4 D1/B-4-r A1-4-D1	5-8 where A1 or D1	45	0-45 S, 0-100% fn gr, med gr	0-28 S, 0-100% fn gr, cobs	
77	F1	5-8	30-90	none	none	
78	B-4-C	5-8	----	61 S	49 S	
79	B-4-D1-Cb	30-35 / 8-15	30 / 35-40	56 S	38 S	
80	Dhb	45-50	43	39-58 S	28-31 S	
81	Dh-F1	50 / 4-8	90	none	none	
82	F1	18-20	90	none	none	
83	B-4/8-r B-4	---	---	0-17 S Rock bench 30-70 ft. wide	0-16 S	
84	F1	4-6	90	Rock bench 30 ft. wide cobs, slabs		

Physiographic unit number	Basic coast zone element	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
85	B-4	---	---	20-44 S, 95-99% fn gr	16-42 S	
86	D1 D1b D1/B-4	15-35	25	23-50 S, 96-99% fn gr,med gr	22-53 S, 99% fn gr	
87	F1	8-10	90	Rock bench 15-20 ft. wide		
88	B-8-r	---	---	Rock bench 30-40 ft. wide slabs, bldrs, cobs		
89	A1-4-r	8	15-20	0-15 cs gr Rock bench 25 ft. wide	none	
90	F1	6-12	15-90	0-36 S Rock bench 20 ft. wide	0-57 S	
90	B-4	---	---	34 S	34-51 S	
92	B-8-r	---	---	Rock bench 10-100 ft. wide		
93	B-8-r-M	---	---	none — reef at water line		
94	B-4 B-4-C	5, dunes	---	40-60 S	25-50	
95	B-8-r F1	---	---	Rock bench 30-110 ft. wide, slabs, cobs, mud, bldrs		
96	A1-4	11	35	Zone 58 ft. wide of coarse gr, cobs, s 20%		
97	B-4 B-4-M	---	---	0-8 S, 90-100% cs gr	0-8 S, muck	
98	A1-1-A1-4	9 9	30 35-45	6 S, 35% cobs, bldrs	18 S, 25% cobs, bldrs	
99	B-8-4	---	---	Rock bench 30-60 ft. wide slabs, cobs, bldrs		

Physiographic unit number	Basic coast zone elements	Height (ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
100	B-4-r B-4	---------	---	0-26 S, 0-85% fn gr, cs gr cobs, slabs Or, rock bench	12-55 no s fn gr, cs gr cobs, slabs 20-100 ft. wide	
101	B-4-!	---	---	none	none	
102	B-4-r	---	---	Rock bench 33 ft. wide		
103	Fl	9	90	No beaches. Flat dolomite shelf, awash		
104	B-4	---	---	21 S, 99% fn gr	23 S	
105	Fl B-8-r B-4	10, where cliff	90, where cliff	Sand beach, 0-40 ft. wide Rock bench, mostly awash		
106	B-4-C	---	---	19 S, 95% med gr	22 S, 98% fn gr	
107	Fl	13	90	No beaches Rock reef awash		
108	Al-4-C	10	35	33 S, 85% fn gr, cobs	24 S, 90% fn gr	
109	B-4-r	---	---	36 cs gr	none	
110	Fh Fl	15-40	45-90	Rubble zone and rock ledge, 15-25 ft. wide. 20-ft. cs gr beach, one point		
111	B-8-4	---	---	Beach zone 30 ft. wide. cs gr, cobs, bldrs		
112	Fh	High	steep	Narrow beach zone		
113	B-4	---	---	10-17 cs gr, cobs	19 cs gr, cobs	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
114	Fh Fl	30-58 mostly	30-90	No beaches Rubble zone 15-35 ft. wide		Figure 19
115	B-4 B-4-R	---	---	0-18 med gr,fn gr	0-14 med gr	
116	Al-4	12	35	No beaches, zone 30 ft. wide of cs gr, cobs, bldrs		
117	Fh	125	30-90	No beaches, zone 30 ft. wide of cobs, bldrs		
118	Fl	15	50-90	No beaches, zone 15-30 ft. wide of cs gr, cobs, slabs		
119	B-4	---	---	Beach zone 16-32 ft. wide of cs gr, cobs, slabs		
120	Fh	95	25-90	Beach zone 10-30 ft. wide of cs gr, bldrs, and slabs		
121	Fh-B-4-r	75-100 above plain	25	Rock bench 30-35 ft. wide		
122	B-4	---	---	Beach zone 24 ft. wide coarse gr, cobs		
123	Fh	75-100	30-90	Beach zone 15-30 ft. wide Bldrs, cs gr, slabs		
123A	Fh-B-4	High, above plain	steep old cliff	Beach zone 30 ft. wide cs gr, cobs, bldrs		
124	B-4	---	---	14-34 S, 50-98% med gr,cs gr	19-34 S, 25-100% cs gr, cobs, bldrs	
125	Fh	150-175	60-90	Beach zone 27 ft. wide cs gr, blocks, bldrs		
126	B-4	---	---	16-31 S, 25-99% fn gr, cs gr, bldrs	16-24 S, 25-99% fn gr,cs gr bldrs	
127	Fh	35	35-90	Beach zone 20 ft. wide cs gr, cobs, slabs, bldrs		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
128	B-4	----	----	Beach zone 25 ft. wide cs gr		
128A	A1-4-r	9	40	Beach zone 28 ft. wide. cobs, slabs, bldrs		
129	F1- B-4	8-15, except plain	90	Beach zone 15-84 ft. wide. cs gr, cobs, slabs, bldrs		
130	B-4	----	----	Beach zone 20-72 ft. wide. S, 99%; fn gr. Narrow part protected by walls and groins		
131	Fh Fh-al-4/8-4 Ah-4/8-r	75-150	20-90	Rock bench or beach zone 0-30 ft. wide. Cobs, bldrs, blocks		
132	B-4	----	----	Beach zone 24-34 ft. wide cobs, bldrs, slabs		
133	F1-r	9	60-90	Beach zone 29 ft. wide cobs, slabs, bldrs, rock bench		
134	B-4-r	----	----	Rock bench 42 ft. wide cobs, slabs, bldrs		
135	F1-r	10	45	Beach zone or rock bench 37 ft. wide. Slabs, bldrs		
136	B-4	----	----	Beach zone 21 ft. wide S, 50%; cs gr		
137	B-8-r B-4-r B-4 B-4/8-r	----	----	Mostly: Rock bench or beach zone 20-35 ft. wide cs gr, cobs, slabs, bldrs Partly: 21 S, 99% fn gr 24 S, 85-99% cs gr		
138	B-4-r F1 B-4 B-4/8-r	6-27 where cliff	45-90 where cliff	Mostly: Rock bench 20-55 ft. wide. cs gr, cobs, slabs, bldrs One point: 21 cs gr 13 cs gr, cobs		Figure 9
139	R	13	45°	Fill; riprap face		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo Number
140	Fl B-4	6-12	90	Beach zone 15-25 ft. wide. cs gr, slabs, bldrs		
141	B-4	---	---	9-13 S, 75-96% med gr, fn gr	17-26 S, 50-98% fn gr, cs gr cobs, bldrs	
142	Al-R	8-15	42-55	Beach zone 10-20 ft. wide. cs gr and blocks		
143	Fh	40	70-90	Beach zone 10-15 ft. wide. cs gr, blocks, slabs		
144	Fh-B-4 B-4-r	50 above plain	steep	Beach zone 8-18 ft. wide. cs gr, slabs, bldrs, ledge		
145	Fl-r	4-12	50-90	Beach zone 0-26 ft. wide. cs gr, cobs, bldrs, ledge.		
146	Al-4	8-25	30-90	Beach zone 0-20 ft. wide. cs gr, slabs, bldrs.		
147	Fh-r	45-125	70-90	Rock bench 10-25 ft. wide. cs gr, slabs		
148	B-8-r B-4-r B-7-r B-4-r-M	---	---	Beach zone 6-30 ft. wide Rock ledge, cobs, bldrs, Riprap, one place.		
149	Fl-r	10-15	90	Beach zone 0-35 ft. wide. cs gr, bldrs, slabs. Rock bench awash.		Figure 21 Figure 22
150	B-8-r B-4/8-r	---	---	Beach zone 24-35 ft. wide. cs gr, cobs, slabs, bldrs, ledge rock.		
151	Al-1-M	10	35	Beach zone 30-35 ft. wide. S, bldrs, mud. Reeds		
152	B-4	---	---	16-31 S, 96-100% fn gr	17-28 S, 95-100% fn gr	
153	B-4/8-r	---	---	Beach zone 5-20 ft. wide. cs gr, cobs, bldrs, ledge rock.		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
154	B-4	---	---	Beach zone 12-30 ft. wide. S, cobs, muck. Reeds in water.		
155	B-8-r B-4/8-r	---	---	Beach zone 10-25 feet. S, cs gr, bldrs, ledge rock.		
156	B-4 B-4-M	---	---	Beach zone 18-27 ft. wide. cs gr, S, muc, bldrs. Reeds in water.		
157	B-4 B-4-M	---	---	Beach zone 0-31 ft. wide. Silt, S, cs gr, cobs, bldrs. Reeds in water.		
158	A1-4	7	45	No beach. Reeds in water to foot bluff.		
159	B-4-M	---	---	Low plain of gravel, probably over bedrock. No beach. Reed marsh		
160	F1 B-4-r	13 where cliff	55	Beach zone 12-20 ft. wide. cs gr, bldrs, ledge rock.		
161	Fh	80-90	90	Beach zone 25 ft. wide. cs gr, bldrs, slabs.		
162	F1	10-18	90	Beach zone 23-27 ft. wide. cs gr, cobs, slabs.		
163	Fh	25-50	60-90	Beach zone 20-27 ft. wide. cs gr, cobs, slabs.		
164	Fh-B-4	40 above plain	steep	Beach zone 20 ft. wide. med gr, cs gr.		
165	Fh	50-55	60-70	Beach zone 20-25 ft. wide. cs gr, bldrs, slabs.		
166	F1-A1-4 F1-B-4	15-30 8-3	45 50	9-17 cs gr, cobs bldrs	11-17 cs gr, cobs, bldrs	
167	F1	15	90	13 cs gr, slabs, bldrs	12 cs gr, clbs bldrs, slabs	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
168	B-4 Fh-B-4-r	75 above plain	38 above plain	11-16 med gr, cs gr bldrs	14-21 med gr, cs gr bldrs, ledge rock	
169	Fh	100-125	35-40	15 cs gr, med gr	12 cs gr,med gr	
170	Fl	18-20	45-60	10 cs gr,med gr	18 cs gr,med gr	
171	B-4 Al-4	6-8 above plain	25° above plain	13-20 S, 0-85% fn gr,med gr cs gr, bldrs	17-23 S, 0-95% fn gr,med gr cs gr, bldrs	
172	Al-1	8	30	24 S, 98% clbs, bldrs	16 S, 95% clbs, bldrs	
173	Ah-1-B-4 Ah-1-B-1	20-30 above plain	25-35 above plain	6-10 S, cs gr clbs, bldrs	12-15 S, cs gr muck	
174	Ah-1	40	35-25	6 S, 99% fn gr	26 S, 75% med gr, cs gr cobs	
175	B-4	----	----	5-14 S, 99% fn gr	5-25 S, 98% fn gr,bldrs riprap and seawalls at places	
176	Al-4	15	50	11 S	19 S; few bldrs	
177	Fh	100	40-45	5-10 cs gr,slabs	30 cs gr,cobs, bldrs	
178	Fh-B-8 Ah-1-B-4 B-4	25-120 above plain	45 above plain	0-15 S, 10-65% med gr,cs gr cobs, bldrs	15-30 S, 10-70% med gr,cs gr cobs, bldrs	
179	Ah-1	55	40-45	5 S	17 S, 70% cs gr,bldrs	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
180	B-4	---	---	15-18 S, 98% fn gr	20-30 S, 75-95% cs gr	
181	A1-4-M	18	10-15	No beach. Reed marsh; muck.		
182	B-4-M B-7-E-M	---	---	6-12 S, 99% fn gr	13-20 S, 99% fn gr	
183	B-1-r B-4-r	---	---	0-12 cs gr	5-22 S, 25-95% fn gr, cs gr cobs, bldrs	
184	B-4 A1-4-B-4	15 above plain	25 above plain	0-5 S	11-40 S, 30-98% cs gr, bldrs	
185	B-4-M B-4-M-R	---	---	No beaches. Reed marsh in water. Riprap one place.		
186	Artificial fill, sea walls, and riprap.					
187	B-4-M	---	---	No beaches. Reed marsh in water. Muck bottom. Silt and clay dredged up.		
188	B-8-M B-8-r-M	---	---	0-12 S, 25-90% med gr, mud Reed marsh in water.	0-75 S, 65-90% mud, cs gr	
189	B-4-M B-4-M-E B-7-M A1-4-M	11 ft. bluff at one point	35 at only bluff	Sand beach 0-20 ft. wide. Reed marsh offshore. Sand bar 10-20 ft. wide at places.		
190	A1-4-M A1-4-R	8-12	35	0-6 S	8-20 S Riprap at one place.	
191	B-4 B-4-M B-4-E	---	---	none.	0-20 S Reed marsh offshore sand bar 8-15 ft. wide	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
192	M-E	---	---	0-20 S	18-30 S Marinette spit. Reed marsh offshore	
193	B-4 B-4-E B-4-R	---	---	5-60 S, 99-100% fn gr	18-40 S 99-100% fn gr, sawdust. One place: no beach; riprap.	
194	Artificial fill behind seawall and riprap.					
195	B-4 B-1 B-4-M B-4-R	---	---	0-25 S, 25-100% med gr,cs gr driftwood One place: no beach but riprap and seawall.	20-41 S, 10-99% cs gr,med gr cobs, bldrs driftwood	Figure 7
196	A1-4	10	30	Beach zone 27 ft. wide. S, 25%. gr,cobs, bldrs.		
197	B-4	---	---	7 S	30 S	
198	B-4-r	---	---	Three rocky points 75-100 ft. long. Ledge rock, cs gr, slabs.		
199	B-4-E	---	---	Beach zone 20-40 ft. wide. S Bar 20-30 ft. wide.		
200	B-4-r	---	---	Point is ledge rock with cs gr and slabs. Beach zone 10-60 ft. wide. cs gr, bldrs, slabs, ledge.		
201	B-4	---	---	10-12 S	20-42 S	
202	B-4-r	---	---	Beach zone 15-50 ft. wide. cs gr, slabs, bldrs, ledge.		

Physio-graphic unit number	Basic coast zone elements	Height (ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
203	B-4	---	---	0-16 S	20-40 S, 99% fn gr, bldrs	
204	A1-4	10	35	none	27 cs gr, med gr bldrs, slabs	
205	B-4	---	---	8-16 S, 98-100% fn gr	20-42 S, 70-99% fn gr, cobs, bldrs	
206	B-4-r	---	---	Beach zone 50-75 ft. wide. cs gr, slabs, cobs, ledge rock.		
207	B-4 B-4-E	---	---	10-12 S	16-40 S, 98-100% bldrs Bar 20-30 ft. wide one place	
208	B-4-r	---	---	Zone 40-75 ft. wide. gr, bldrs, slabs		
209	B-4	---	---	10-35 S, 94-99% med gr, fn gr	17-40 S, 92-97% fn gr, med gr bldrs	Figure 6
210	A1-4	10	40	Zone 71 ft. wide of cs gr, cobs, slabs, bldrs		
211	B-4	---	---	24-42 S, 70-99% med gr	19-37 S, 70-99% cs gr, fn gr bldrs	
212	B-4/1-r	---	---	Zone 100-200 ft. wide cs gr, s, slabs, bldrs, ledge		
213	B-4 B-4/1	---	---	17-21 S, 92-99% med gr	54 S, [illegible]0-99% cs gr, mud	
214	A1-4	13	30-45	Beach zone 11 ft. wide. cs gr, cobs, bldrs, mud		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
215	B-4 B-1 B-4-r-M B-4/8	---	---	Beach zone 90-175 ft. wide. cs gr, cobs, bldrs, till, ledge.		
216	B-4/8-r	---	---	Beach zone 100-160 ft. wide. S, 25%. cs gr, slabs, bldrs, ledge rock.		
217	B-4	---	---	25-40 S, 75-100% fn gr, med gr	26-50 S, 50-100% fn gr, cs gr	
218	B-4-B-7-M B-4-M	---	---	Wet zone 50-300 ft. wide. Mud, sand, reeds in muck: no true beaches.		
219	B-4 B-4-C	---	---	23-44 S	17-21 S	
220	B-4/8-r	---	---	Beach zone 66 ft. wide. cs gr, ledge rock.		
221	B-4/1	---	---	Beach zone 45 ft. wide. cs gr, ledge rock.		
222	E-C	---	---	11-23 S	10-71 S	
223	E-M	---	---	No beaches. Reed marsh offshore.		
224	B-4-M	---	---	No beaches. Reed in offshore.		
225	A1-4-M	18	30	No beaches. Reeds in off-shore. Bar 300 yd. offshore.		
226	B-4	---	---	Low sand plain		
227	E-R	---	---	Bar and fill. Much of shore held by riprap. Long stone jetties.		
228	R	---	---	Low sandy plain and fill held by walls and riprap.		
229	B-4-M	---	---	16 S, wood	25 S	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
230	Ah-4-M	30-35	40	No beaches. Wet zone 10-40 ft. wide. Mud, gr, reeds.		
231	B-4	---	---	Beach zone 0-30 ft. wide. S, 5%. Gr, wood debris		
232	A1-4-B-4-M	8 above plain	30 above plain	No beaches. Reeds in water offshore.		
233	A1-4-M Ah-4-M	10-22	30-50	No beaches. Damp zone 5-40 ft. wide. Mud, gr. Reed marsh in water. Road fill 90 ft. wide, one point.		
234	Ah-4-r-M	90-100	40	Damp beach zone 30-75 ft. wide. Gr, slabs, ledge, mud. Reeds offshore.		
235	Ah-4	25	45	Beach zone 0-18 ft. wide. S, fn gr. Riprap along part of shore		Figure 24
236	B-4 B-4-M A1-4-B-4	10 above plain	25 above plain	0-39 S, 95-100% fn gr,cs gr	0-18 S, 99% fn gr	
237	B-4-M B-1/8-M A1-4-B-4-M	12 above plain	30 above plain	Beach zone 0-12 ft. wide. cs gr. Reed march in water.		
238	B-4/8	---	---	No beaches. Damp sandy zone at water a few ft. wide.		
239	B-4-M A1-4-B-4-M A1-4-M	12-25 above plain	30-35 above plain	Beach zone of S, 0-20 ft. wide. Reed marsh offshore.		
240	Ah-M Ah-4-M	25-30	35-40	Beach zone of S, 10-12 ft. wide. Reed marsh offshore.		
241	B-4-M	---	---	Beach zone of S, 10-25 ft. wide. Reed marsh offshore.		
241A	A1-4-A1-4-M	12 7	40 40	8 S	6 S	
242	B-4-M	---	---	No beach. Reed marsh offshore.		

Physiographic unit number	Basic coast zone element	Height (ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
243	B-4	---	---	Beach zone 55 ft. wide. S, 98%. Fn gr		
244	A1-4-A1-4	12 / 10	35 / 40	16 cs gr	9 S, 40%. cs gr	
245	B-4	---	---	25 S, 70% cs gr, bldrs	34 S, 25-90% cs gr, bldrs	
246	F1	15	90	Zone 21 ft. wide of slabs and cs gr.		
247	Fh Fh-r	28-50	60-90	10-12 cs gr, bldrs	10-12 S, 30%	
248	B-4/8 B-4/8-r B-4-r	---	---	20-35 cs gr, slabs	75-150 cs gr, slabs ledge rock	
249	Fh-B-4	30-35 above plain	90 above plain	Zone 30-35 ft. wide of cs gr and slabe		Figure 20
250	Fh-r	30	90	Zone 10-15 ft. wide of cs gr and slabs		
251	A1-4-r F1-r	4-10	10-90	Zone 60-300 ft. wide cs gr, slabs, ledge rock.		
252	B-4-r B-4/8-r	---	---	Zone 90-250 yd. wide. cs gr, slabs, ledge rock.		
253	B-4	---	---	28 S	48 S, 99% bldrs	
254	B-4/8-r B-4-C-r	8-10 above plain	30 above plain	23 S, fn gr One place: rock bench 250-400 ft. wide.	65 S, mud, gr, slabs	
255	B-4	---	---	Beach zone 75-200 ft. wide. Mud, S, gr, bldrs.		
256	B-7-M	---	---	Beach zone 75 ft. wide Mud, S, gr. Reed marsh offshore.		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
257	B-4-r B-4/8-r	---	---	Beach zone 100-250 ft. wide. Mud, cs gr, slabs, ledge.		
258	B-4-C	Dunes 4 ft. high	---	40 S	22 S	
259	B-4	---	---	40 S, fn gr	70-80 ledge rock, angular gr	
260	B-4-C	dunes 10 ft. high	---	30 S	17 S	
261	B-4-r-M B-1/8-r-M B-4/8-r-M	---	---	Zone 30-200 ft. wide. Rock bench, strewn with mud, angular gr, slabs.		
262	B-4-M B-7-M A1-4-B-4-C-M	15 above plain	30 above plain	Mostly: no beaches. Wet zone of muck, S, gr up to 150 yd. wide. Reed marsh offshore. Bldrs.		
263	B-4	---	---	53- S, 75% fn gr	46 S, 80% med gr, cs gr	
264	B-1-M B-4-C-M	Dunes 4	---	Beach zone 100-275 yd. wide. Sand, a few pebbles, mud. Reed marsh offshore.		
265	B-6-C	Dunes 8	---	18 S	60 S, 90% sawdust, wood	
266	R	Low seawalls hold artificial fill. Low plain.				
267	B-4 B-4C	Dunes 4	---	30-37 S	39-45 S	
268	B-4-r B-4-C-M	Dunes 3	---	Damp zone 75-180 ft. wide. S, gr. Slabs, rock ledge at one point. Reeds offshore.		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
269	B-4-r B-4/8-r-M B-8-r-M	----	----	35-54 S, 90-99% med gr Elsewhere: zone 30-88 ft. wide of gr, slabs, ledge. Reed marsh offshore	57-100 S, cs gr, slabs ledge rock	
270	B-4-M B-1-M	---	---	No beaches. Wet zone 90-125 ft. wide of S, muck. Reed marsh offshore.		
271	B-4-C	Dunes 4	---	36 S	45 S	
272	B-4-M Dl-B-4-M Fh-B-7-M Al-B-7-M	Dunes 20 Old bluff 10 Cliff 100	Cliff 35	Wet beach zone 0-200 ft. wide. Muck, S, gr, bldrs, till. Reed marsh offshore.		
273	Ah-4-M	20-25	35	Zone 20 ft. wide of cs gr. Reed marsh offshore.		
274	Fh-B-4/8-r	Cliff 50 Bluff 15	Cliff 65-90 Bluff 25	Beach zone 40-47 ft. wide. cs gr, slabs, rock bench.		
275	Ah-C	35	17	33 S, 98% cs gr	23 S, 25-99% cs gr	
276	B-8-r	---	---	Beach zone 36 ft. wide. S, 10-95% cs gr, slabs, rock ledge.		
277	Fh	75-100	steep			
278	Fl-Fl-B-8-r	80-100 above plain	10-15 above plain	Beach zone 32 ft. wide. cs gr, slabs, bldrs Little S.		
279	B-1/8-r	---	---	Beach zone 40-45 ft. wide. cs gr, slabs, bldrs, ledge.		
280	B-8-M B-4/8-M	---	---	No beach. Reed marsh offshore.		
281	B-8-r	---	---	Beach zone 25 ft. wide. cs gr, slabs, rock ledge.		
282	B-4-M	---	---	No beaches. Wet zone 25 ft. wide. Reed marsh.		

Physio-graphic unit number	Basic coast zone elements	Height (ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
283	Fh-B-8-r	30 above plain	65-90 above plain	Zone 17 ft. wide. cs gr, rock bench.		
284	Fh-r	65	45-90	Zone 14 ft. wide. Cs gr. Rock bench below.		
285	B-8 B-8-r B-8-r-M	---	---	Zone 30-250 ft. wide. S, 10-100%. Cs gr, slabs, rock bench. Reed marsh at one place.		
286	Fh-r-M	80	20-90	Zone 10 ft. wide. cobs, cs gr. Ledge inferred.		
287	Fh-Fl-r	70-80 / 10	15-20 / 45	Zone 36 ft. wide. Rock bench; cs gr, slabs.		
288	Ah-1-B-4-r	25 above plain	30 above plain	Zone 25 ft. wide. Rock bench with slabs, cs gr.		
289	Fh-r Fh-Fh-r	25-60 total	20-90	Zone 15-25 ft. wide. Rubble, slabs, blocks. Rock ledge.		
290	Dlb-C	Dunes 10 Bluff 15	Bluff 30	14 S, 99% fn gr	10-25 S, 50-60% cs gr, cobs	
291	B-4	---	---	22 S, 99% fn gr	40-200 S, 60-99% fn gr, cs gr, cobs	
292	Fh-r-	200	31-40	Zone 28 ft. wide. cs gr, cobs, rock ledge.		
293	Fh-B-4	205 above plain	90	Beach zone 25 ft. wide. cs gr.		
294	Fh	200	45-90	Zone of bldrs, blocks and slabs, 15 ft. wide.		
295	B-4 Al-4-C/B-4	15 above plain	moderate above plain	20 S	24 S, 95% cs gr	

Physiographic unit number	Basic coast zone elements	Height (ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
296	B-4/1	----	----	Beach zone 60 ft. wide. cs gr, some mud.		
297	B-8-r B-4-r	----	----	Beach zone 95-195 ft. wide. cs gr, slabs, ledge rock. Some mud or silt.		
298	D1-Cb	20	6	34 S, 93% fn gr	34 S, 99% fn gr	
299	B-4-C	5-15 dunes	----	18 S	31 S	
300	B-8-r	------	----	Zone 63 ft. wide. cs gr on rock ledge.		
301	D1-C-r D1-C	10-25, dunes	----	34-45 S, 97-99% fn gr	50-192 S, 75%; gr. Rock bench	
302	B-4/8-r	----	----	Low damp gravelly shore. Ledge rock below.		
303	B-7-M	----	----	Wet marshy shore. No beach.		
304	B-4-r	----	----	Zone 160-200 ft. wide. cs gr, slabs, over rock bench.		
305	B-4-Cb-r	Dunes 8-15 nip 10	35, nip	25 S	15-35 S, 50% cs gr, ledge rock	Figure 11
306	B-8-r	----	----	Beach narrow; cs gr and ledge rock.		
307	B-4-C-r-M	Dunes 6	----	Beach zone 100-125 ft. wide. Wet; cs gr, S, rock ledge below.		
308	B-8-r-M	----	----	Beach narrow; cs gr and ledge rock. Reed marsh offshore		
309	B-8-r	----	----	Beach narrow; cs gr, bldrs, ledge rock.		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
310	B-8-r-M	---	---	Beach zone narrow; cs gr, bldrs, ledge rock. Reed marsh offshore.		
311	B-4-r B-4	---	---	Zone 67-140 ft. wide. cs gr, slabs, ledge rock. One place: 39 S	28 S	
312	Ah-4 Ah-3/4/1	45-90	15-40	19-27 S	27-30 S	
313	Ah-4-B-4 B-4-C-r	75-80 bluff	35-40 bluff	Zone 47-80 ft. wide. cs gr, slabs, bldrs, ledge. One place: 18 S	16 S	
314	B-8-r	---	---	Beach zone narrow; cs gr, bldrs, ledge rock.		
315	Ah-4-B-4-r Al-4-r	15-25	370	Beach zone 20-50 ft. wide. cs gr, cobs, slabs, ledge. One place: 46 S	36 S	
316	Ah-4-r	20	40	Beach zone 48 ft. wide. S, 50%. cs gr, cobs.		
317	B-4-r B-4/1 B-4-Cb D1/B-4/C-r	Dunes, 5-20	---	22-135 S, 92-100% med gr	21-75 S, 90-100% med gr, cs gr slabs, ledge	
318	Ah-4-B-4-C	Bluff 25 Dunes 6	Bluff 25	21 S	14 S	
319	B-4-r	---	---	Beach zone narrow. S, 50-90%. cs gr. Rock reef in water.		
320	B-4-C	---	---	20-33 S, 99% fn gr	20-29 S	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
321	B-4-r	----	----	Beach zone 340 ft. wide. S, 50% cs gr, slabs. Rock ledge.		
322	B-4 B-4-C	----	----	20-58 S	36-43 S	
323	B-4-r	----	----	Zone 87 ft. wide. Inner 1/4 cs gr. Outer 3/4 rock bench.		
324	B-4	----	----	33 S, 85% wood	35 S wood debris	
325	D1-C	Dunes 15-20	----	26-44 S, 95% wood	47-50 S, 98% wood	
326	B-8-r	----	----	Rock bench 20-60 ft. wide. cs gr storm beach.		
327	B-4 B-4-C D1-B-4	Dunes 8	----	34-405 S, 85-95% Sawdust wood, fn gr	19-66 S, 25-95% sawdust	
328	B-8-r B-4/8-r	----	----	Rock bench 90-200 ft. wide cs gr, bldrs, slabs		
329	D1-C D1-r	Dunes 5-20	----	52-123 S, 20-100% sawdust	16-39 S, sawdust wood Ledge in water.	Figure 17
330	B-4-C-r B-4/8-r B-4-Cb	Dunes 4-20	----	Beach zone 20-375 ft. wide. Sand, logs, slabs, ledge. Also: 22-90 S, 80-100% cs gr, logs	26-64 S, 85-100% cs gr, cobs bldrs, sawdust slabs, ledge rock	
331	D1-Cb	Dunes 6-10 nip 6	Nip 35	105 S	40 S	
332	F1-r	5'	90°	Narrow rocky beach zone.		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
333	B-4-Cb B-4-C-r	Dunes 8-28 nip 10-12	Nip 35	35-75 S, 99% fn gr	20-54 S, 95-100% med gr	
334	Dl-Cb Dh-Cb Dl/B-4-Cb	Dunes 6-55 Bluff 5-10	Bluff 30-40	39-55 S, 99-100% fn gr	48-74 S, 99-100% fn gr	Figure 12
335	B-8-r B-4/8-r Fl-r	----	----	Beach zone 0-200 ft. wide. Rock bench with S, cs gr, slabs, bldrs. Bench awash if no beach		
336	B-4-C	Dunes 7	----	48 S	31 S	
337	B-8-r Al-8	Bluff 6-8	Bluff 90	No beach. Zone 0-60 ft. wide of slabs, bldrs, cs gr, ledge rock.		
338	B-4/8-r B-4/8-Cb B-4-Cb-r	Dunes 8-25 nip 5-12	Nip 35-40	Rock bench 30-195 ft. wide, with bldrs, cs gr, sand at places.		
339	R	----	----	Artificial fill behind seawall.		
340	B-4-C B-4-C-R	----	----	Partly: Fill of pumped sand 250 yd. wide. Elsewhere: 40-45 S	70 S	
341	B-4-r	----	----	Zone 40-200 ft. wide of cs gr, cobs, bldrs, over ledge rock.		
342	B-4-E	----	----	cs gr beach ridge outside wet marsh.		
343	B-4-r	----	----	Narrow beach zone of rock and cs gr.		
344	B-4-C	Low dunes	----	Narrow beach of sand.		
345	B-4	----	----	Narrow beach of sand.		
346	B-4-r	----	----	Narrow beach zone of rock and cs gr.		

Physiographic unit number	Basic coast zone elements	Height (ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
347	B-4-r B-4-C-r	Dunes 5-12	—	Beach zone 40-200 ft. wide: bldrs, slabs, rock bench. One place: 10 S, bldrs	 80 S, bldrs, ledge rock	
348	B-4 B-4-C D1	Dunes 5-25	—	7-12 S, 96-100% bldrs One Place: zone 30-125 ft. wide of cs gr, cobs, bldrs	27-31 S, 96-100% cobs, bldrs	
348A	D1-C	Dunes 5-35	—	20 S	35 S	
349	B-4 B-4-r D1-C	Dunes 4-25	—	Zone 40-60 ft. wide of cs gr, cobs, slabs, bldrs. Ledge inferred. Elsewhere: 10-15 S, 30-100% fn gr, bldrs	 35-65 S, 10-100% mud, clbs, bldrs.	
350	B-4	—	—	12 S, 98% fn gr	25-87 S, 88% fn gr	
351	B-4-r	—	—	Narrow beach zone of cs gr and ledge rock.		
352	B-4	—	—	Narrow sand beach.		
354	B-4-E	—	—	Narrow sand beach behind sand bar.		
355	B-4 B-4-C B-4-E	—	—	0-25 S At some places: zone 50-60 ft. wide: S, 25%; cs gr, cobs, bldrs.	20-85 S, 92-100% bldrs	
356	B-4-r	—	—	Narrow beach zone of gr and ledge rock.		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
357	B-4 B-4-C	—	—	Generally zone 25-90 ft. wide. S, 10-90%; cs gr, cobs, bldrs. One place: 15 S	 40 S	
358	B-4/8-r	—	—	Zone 30-60 ft. wide. Bldrs, slabs, ledge rock.		
359	B-4-C	Dunes 6-18	—	17-20 S	27 S	
360	B-4-C-r B-8-C-r B-4/8-r	Dunes 8-15	—	10 S One place: zone 20-30 ft. wide of slabs, cobs, and bldrs. Ledge inferred.	12-40 S, 95% cs gr, cobs	
361	B-4 B-4-C	Dunes 9-15	—	0-32 S	41-85 S	
362	B-4/8-r	—	—	Zone of cobs, slabs, bldrs over ledge rock, 20-30 ft. wide.		
363	B-4-C	—	—	15-22 S	40-46 S, bldrs	
364	B-4/8-r	—	—	Zone 20-60 ft. wide of cobs, slabs, bldrs, ledge rock.		
365	B-4	—	—	15 S	76 S, bldrs	
366	B-4/8-r	—	—	Zone 30-40 ft. wide of cobs, slabs, bldrs, ledge		
367	B-4-C	Dunes 15-25	—	20 S	37 S	
368	B-4/8-r	—	—	Zone 40-50 ft. wide of cobs, slabs, bldrs, ledge rock.		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
369	B-4-C	Dunes 15-25	—	15 S	40 S	
370	B-4/8-r	—	—	Zone 20-40 ft. wide of cs gr over rock ledge.		
371	B-4-C	—	—	10 S	27 S	
372	B-4/8-r	—	—	Zone 30-50 ft. wide of cobs, slabs, bldrs. Ledge inferred.		
373	B-4-C	—	—	10 S	30 S	
374	B-8-r	—	—	Zone 40-60 ft. wide of cobs, slabs, bldrs. Ledge rock inferred.		
375	B-4-E-M	—	—	25-35 S	90 S Reed marsh behind bar	
376	B-4-r B-4 B-4-M B-8-r Ah-4-B-4	Bluff 150 above plain	Bluff 30	Mostly: zone 15-100 ft. wide of S, muck, reeds, cobs, bldrs, ledge rock. At 2 places: zone of wet S and muck 0-100 ft. wide. Reeds. At 2 places: 10-17 S, bldrs	 17-40 S, csgr,slabs ledge rock	
377	Ah-4-B-4	Bluff 60-165	Bluff 35-45	Mostly: 5-33 S One place: zone 15-40 ft. wide of cobs and bldrs.	 27-36 S, few bldrs	
378	Ah-3/1 Ah-4/1 Ah-r	80-175	36-43	8-20 S, 99-100% cs gr,bldrs	25-60 S, 60-100% cobs, bldrs	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
379	Dl/Al-l-B-4	Bluff 11	Bluff 25	15 S	30 S, few bldrs	
380	Dh-C Dlb Dhb Dh-Cb	Dunes 15-70 Bluff 35	30-35	8-45 S, 98%, bldrs In places, single zone of S, 10-35 ft. wide.	22-50 S, 70-100% fn gr, cobs	
381	B-4-r Dl-r	Dunes 20-25	---	5-35 S, 10-100% cs gr, med gr	15-50 S, 10-95% cs gr, slabs, bldrs, ledge	
382	B-4-C	---	---	20-25 S	70 S	
383	B-4 B-4-r Al-4-B-4-r B-8-r Fh-Al-4-B-4-r	Cliff 60 Bluff 10-30	Cliff 75 Bluff 35-25	0-52 S, 0-100% cs gr One place: 40-70 ft. zone of cs gr, slabs, ledge rock.	10-65 S, 0-100% fn gr, cs gr bldrs, ledge	
384	B-4	---	---	40 S, 99% fn gr	45 S, 99% fn gr	
385	B-4-r B-8-r Fh-Al-4-B-4 Fl-B-4	Cliff or bluff 18-25	Cliff or bluff 30-60	0-22 S, 10-85% med gr, cs gr	0-75 S, 10-40% cs gr, slabs bldrs, ledge	
386	B-8 B-8-C B-8-r	---	---	0-50 S, 10-100% cs gr	12-40 S, 20-95% med gr, cs gr, cobs, ledge	
387	Al-4	10-15	30	Beach of S and gr		
388	B-4-C	Dunes 5-15	---	0-23 S	34-38 S	
389	B-4-r	---	---	30 S, 20% cs gr, bldrs	40 S 15% cs gr, bldrs ledge	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
390	B-7-M	---	---	Narrow wet sandy beach zone. Reed marsh offshore		
391	B-3-C-r	Dunes 8-10	---	Beach zone of sand. Rock ledge mainly awash.		
392	B-4-Cb	Dunes 8	---	0	38 S	
393	B-4-r	---	---	0-30 gr storm beach	48-75 S, 10% cs gr, cobs, slabs, bldrs ledge	
394	B-4 B-4-Cb	Dunes 6-10	---	0-38 S, 95-100%	22-38 S, 20-100% fn gr, cs gr	
395	B-4-Cb B-4-r B-3-r	Dunes 8-15	---	23-135 S, 80-100% med gr	30-45 S, 10-100% med gr, cs gr ledge rock	
396	B-4-r-M	---	---	Rock bench, submerged. Bldrs, reed marsh.		Figure 23
397	B-4-C	Low dunes	---	Sandy beach zone.		
398	Dl-Cb Dh-Cb Dlb Dhb	Dunes 8-100	Dunes 10-32	0-342 S, 80-99% med gr, bldrs	17-100 S, 85-98% fn gr, med gr cs gr, bldrs	
399	Ah-Dlb Dh-Al-4-Cb	Dunes 5-90 Bluff 20-60	Bluff 30	8-33 S, 50-98% fn gr, cs gr	25 S, 10-75% cs gr, med gr	
400	B-4 Ah-B-4	Bluff 90	Bluff 30	21-100 S, 65-94% cs gr	24-42 S, 50-95% fn gr, cs gr	

Physiographic unit number	Basic coast zone elements	Height(. .) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
401	Ah-4/1-Dhb Ah-1/4-Dlb	Bluff 35-150 Dunes 10-50	Bluff 35	0-40 S, 98-100% bldrs	33-42 S, 98-100% bldrs	
402	Ah-4/1 Ah-1/4-Al-4-Dhb Ah-1-Al-4-Cb Ah-4/1-C	Bluff 70-150 Dunes 10-75	Bluff 30-35	12-45 S, 97-100% fn gr, bldrs	15-48 S, 93-100% fn gr, med gr bldrs	
403	Ah-4/1/4	200-250	30-35	25-42 S, 97-100% cobs, bldrs	25-42 S, 97-99% fn gr, bldrs	
404	Ah-Dh/Al-4 Ah-B-4-Dl-Cb Ah-1-B-4-Cb Al-B-4	Bluff 75-200 Dunes 10-75	Bluff 30 Dunes 10-35	0-40 S, 97-100% cs gr, bldrs	20-38 S, 94-98% fn gr, cs gr bldrs	
405	Ah-4/1	125	30	18 S	48 S	
406	Ah-1-B-4	Bluff 125	Bluff 30	27 S	33 S	
406A	Dhb Dlb-Cb Ah-Dl-Cb	Dunes 12-70	Bluff 20-35	8-42 S, 88-100% med gr	10-27 S, 95% fn gr	
407	B-4 B-1 Al-4-B-4	Bluff 10	Bluff 25	0-21 cs gr	0-36 till, cs gr, med gr, bldrs One place: S, 100%	
				In part, riprap and seawall.		
408	Dh-Cb	Dunes 10-75	10-32	12-15 S	42-45 S	
409	B-4	——	——	0-15 cs gr	16-18 cs gr	
410	Al-4/1	20-25	40	none	10-12 med gr, cobs	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
411	Fh-Ah-4 Fl B-4	20-55	25-90	0-19 cs gr, cobs fill in part	0-15 cs gr, cobs bldrs	
412	Fh-B-4-r C/B-4-r	cliff 35	Cliff 30	0-39 cobs, cs gr	0-23 cs gr, cobs bldrs	
413	Al-1 Ah-4-Ah-4	75 12-25	30 30-60	0-18 cs gr	10-12 S, 0-25% cs gr, bldrs	
414	Fh-B-8-R	Cliff 50-60	Bluff 30	Shore held by seawall and riprap.		
415	Fh-B-4	Cliff 40	Cliff 30	none	12-18 cs gr	
416	Ah-4 Ah-4/B-Fl Fh-Ah-4 Fh-Fl B-8	Cliff 20-90 Bluff 20-75	Cliff 20-30 Bluff 20-30	0-31 cs gr, cobs bldrs	13-45 S, 0-20% cs gr, cobs, bldrs	
417	B-4 R	Fill 8-15	----	21-36 S, 20-95% fn gr, cobs	18-50 S, 10-25% cs gr, cobs bldrs	
418	R			Fill along low plain.		
419	B-4-r Al-4 Dlb-C	Bluff 12 Dunes 5	Bluff 35-40	9-35 S, 10-99% cs gr	15-120 S, 10-95% cs gr, bldrs ledge rock	
419A	Dh-Cb	Dunes 15-75	30-45	12-30 S	24-29 S, 97-99% fn gr	
419B	Ah-4 Al-4 Ah-3/4-C	Bluff 35-75	10-30	15-35 S, 10-97% med gr, cs gr	16-50 S, 20-95% fn gr, med gr cs gr	

Physiographic unit number	Basic coast zone elements	Height (ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
419C	B-4	----	----	0-14 S, 20-90% cs gr, med gr bldrs	17-25 S, 20-95% med gr, cs gr bldrs	
419D	B-4-r Al-B-3-r	Bluff 15-20	Bluff 20	12-50 fn gr, cs gr bldrs	20-130 fn gr, cs gr bldrs, ledge	
419E	Dlb	Dunes 20-30	30	12 S, 93-95% cs gr	20 S. 90-92% fn gr	
419F	B-4-r Al-4-B-4-r	Bluff 20-25	Bluff 20-25	0-90 S, 10-85% fn gr, cs gr	10-180 S, 10-60% cs gr, bldrs slabs, ledge	
419G	Dlb Dl-Cb	Dunes 8-40	Dunes 10-40	12-27 S	25-36 S, 96-99% fn gr	
419H	B-8-r	----	----	Beach zone of gr and ledge rock		
419I	Dl Dl-Cb	Dunes 5-35	----	Bar of S (95%) and fn gr encloses lagoon. Bar and lagoon 150 ft. wide.		
419J	B-4-C B-4-Cb B-4-C-r Al-4/1-C	Dunes 3-35 Bluff 10-25	20-90 where present	8-30 S, 30-100% fn gr, cs gr Two points of cs gr and bldrs, 115 and 375 ft. long.	12-60 S, 5-98% fn gr, cs gr bldrs	
420	Ah-4/1-Al-1-B-4	30 20-25	30	none	20 cs gr, bldrs	
421	Ah-1 Ah-3/4/1/8	25	30	9 S, 95% cs gr	20 S, 90-92% fn gr	
422	Fh Fl	18-30	30-90	0-21 S, 75% cs gr	0-30 S, 50-70% cs gr, slabs	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
423	Al-4/1 Al-4-Cb Al-4/8 B-2/8	10-25	15-35	10-50 S, 0-100% fn gr, cs gr	14-50 S, 0-100% fn gr, med gr cs gr, bldrs	
424	B-4 B-4-C B-4-r	Dunes 5-20	---	5-21 S, 10-98% fn gr, cs gr	9-35 S, 0-97% fn gr, med gr cs gr, bldrs	
425	Ah-4/1 Ah-4/5	21-25	35-40	15-38 S, 70-90% cs gr, bldrs	14-27 S, 65-94% fn gr, bldrs	
426	Dl-C B-4	Dunes 5-15	---	7-20 S, 80-98% fn gr, cs gr	18-47 S, 30-98% fn gr, cs gr clbs, bldrs	
427	Ah-3/4/8	20-25	37	45 S, 98% fn gr	26 S, 95% fn gr	
428	Dl-B-4-r Dlb-C Dl-Al-4/5	Dunes 5-30 Bluff 10-25	Bluff 35-45	23-32 S, 40-96% fn gr, cs gr bldrs	10-28 S, 25-98% fn gr, bldrs	Figure 18
429	Dl/Al-4/1	Dunes 10-15 Bluff 18	45	none	29 S, 99% fn gr	
430	Dl Dlb Dl-C	Dunes 3-40 Nip 3-15	15-35	15-63 S, 65-100% fn gr, cs gr	17-40 S, 85-99% fn gr, cobs bldrs	
431	B-4 B-4-C Al-4	Bluff 6-8	Bluff 30	0-75 S, 97% fn gr, bldrs	0-55 S, 95-99% fn gr, bldrs	
432	Al-4-C	8	20	25 S, 70% med gr	50 S, 25% fn gr, med gr	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
433	B-4 D1-B-4 B-4-C A1-4-B-4-C	Dunes 5-20 Bluff 12-15	30-38	0-40 S, 65-97% fn gr, cs gr bldrs	10-35 S, 65-97% fn gr	
434	Ah-1-D1-C	Bluff 60 Dunes 3-30	Bluff 43	20 S, 92% fn gr	9 S, 97% fn gr	
435	A1-4-C A1-4	Bluff 5-18	30-35	12-18 S, 65-99% fn gr	14-25 S, 99% fn gr	
436	Ah-1-A1-4/1 Ah-4-C	40-70 18-20	30-45	8-30 S, 93-98% fn gr, bldrs	12-15 S, 90-97% fn gr, till	
437	A1-4-C	10-15	35-40	16-23 S, 97-99% fn gr	21-32 S, 97-99% fn gr	
438	B-4	—	—	13-30 S, 95-97% fn gr	19-27 S, 97-98% fn gr	
439	Ah-4/1/5-A1-4	40-100 10-20	30-38	No beaches. Shore is fill held by riprap.		
440	B-4 B-4-R	—	—	6-15 S In part, seawall along beach.	6-15 S	
441	A1-4/1 B-4 A1-4	10-20	10-90	0-15 S, 50-100% fn gr, med gr bldrs	0-15 S, 50-98% fn gr, cs gr cobs, bldrs	
442	Ah-4	200	37	Beach zone 10-15 ft. wide, S and fn gr. Riprap holds road.		
443	A1-4 B-4 Ah-4-A1-4 A1-4-A1-4	15-30 12-20	10-40	0-15 S, 20-98% med gr, cs gr bldrs	4-25 S, 20-99% cs gr, cobs bldrs	

Physiographic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
444	B-4 B-4-M	---	---	30 S, 97% fn gr In part: wet beach 10-20 ft. wide, s and muck; reed march offshore.	25 S, 97% fn gr	
445	Ah-1 or 4 Ah-4-Ah-4	40 30-100	35	8-20 S, 80-100% fn gr, bldrs	10-16 S, 10-90% cs gr, cobs, bldrs	
446	D1 Ah-1-D1	Dunes 5-40 single bluff 30	10-30	9-28 S, 70-100% fn gr, bldrs	10-23 S, 75-100 med gr, bldrs	
447	A1-4 Ah-1-A1-1	50-60 18-20	30	7-12 S, 90-98% med gr, bldrs	7-14 S, 75-97% cs gr, bldrs	
448	D1-B/4-0 D1/B-4-0-M B-4	Dunes 5-25	---	6-12 S, 92-100% fn gr	12-22 S, 40-100% med gr	
449	A1-4 A1-4-A1-4	15 15-20	5-30	12-15 S, 88% fn gr	27 S, 90% fn gr	
450	B-4	---	---	7 S	9 S	
451	A1-4 Ah-4-A1-4	70 20	35	9 S	6 S Riprap	
452	B-4	---	---	5-12 S	10-14 S	
453	A1-4 Ah-4-A1-4 B-4	17 8-18	10-30	4-20 S, 65-100% fn gr, cs gr bldrs	9-65 S, 20-98% fn gr, cs gr cobs, bldrs	
454	Ah-4	25	30	none	9 S, 40% cs gr	

Physiographic unit number	Basic coast zone elements	Height (ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
455	B-4 B-4-M B-4-R	—	—	5-37 S, 98-100% fn gr	12-21 S, 97-100% fn gr	
				From Traverse City northwest: shore protected by fill and seawalls or piling.		
456	Al-4	12-20	10-30	0-10 S, 50-100% fn gr, cs gr bldrs	11-15 S, 10-99% fn gr, cs gr bldrs	
457	Ah-2 Ah-2/5-Al-4	50-75 20-100	35-40	none	10 S, cobs, bldrs	
458	Al-4-M Al-4-Al-4 Al-4-B-4	20-30 10-18	10-30	0-26 S, 0-99% fn gr, med gr bldrs	11-17 S, 50-95% fn gr, cobs bldrs, muck	
				One place: reed marsh		
459	B-4	—	—	9 S	21 S	
460	Al-1	20	40	4 fn gr	12-14 S, 25% cobs, bldrs	
461	B-4	—	—	22 S, 97% fn gr	30 S, 96% fn gr	
462	Ah-1	90-100	40	4-8 S, 95% fn gr	24 S, 90% fn gr, bldrs	
463	Al-4 Ah-2/5/4-Al-4 Ah-4-Ah-4/1	15-130 12-25	15-43	0-45 S, 20-100% fn gr, med gr cs gr	9-33 S, 0-95% fn gr, cs gr cobs, bldrs	Figure 3
464	B-4 Al-4-B-4	Bluff 8-15	30	0-11 fn gr	3-12 S, 50-100% fn gr, fill	
				Reed marsh at one place.		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
465	A1-4-A1-4 A1-4 B-4	10-15 10-25	10-35	0-9 S, 15-90% fn gr,med gr cs gr	6-15 S, 20-92% fn gr,cs gr cobs, bldrs	
466	B-4	----	----	none	16 S, 97% fn gr	
467	A1-4-A1-4	15-18 15-18	30	3 cs gr	19 S, 35% cs gr	
467A	B-4	----	----	14 fn gr	21 S, 25% fn gr	
468	A1-4	6-18	10-30	0-12 S, 15-99% fn gr,med gr	0-45 S, 10-99% fn gr,med gr cs gr, cobs. Riprap one place.	
469	B-4	----	----	10-12 S	20-38 S, 50-96% fn gr,cs gr bldrs	
470	A1-4-A1-4	20 15-18	25-30	5 cs gr	20 cs gr, cobs bldrs -- zone of seepage	
471	B-4 B-4-M	----	----	0-18 S, 99% fn gr Reeds offshore	20-30 S, 75-99% muck, cobbles one place.	
472	A1-4	Low	15-25	Sandy beach zone.		
473	B-4	----	----	0-10 S, 25-100% fn gr,med gr mud	21-51 S, 65-99% fn gr,med gr cs gr, cobs bldrs, mud	

Physiographic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
474	Al-4	10-25	20-40	0-20 cs gr	13-22 S, 10-40% cs gr, cobs bldrs	
475	B-4	----	----	none	30 cs gr, cobs bldrs	
476	Al-4	10	15	none	17 fn gr, cobs bldrs	
477	B-4	----	----	0-20 S, 65% fn gr	15-22 S, 20-100% fn gr	
478	Al-4	10	10-15	12 S, 70% med gr, bldrs	33 S, 35% med gr,cs gr mud	
479	B-4	----	----	16 S	15 S	
480	Dl-Cb Dl-C	Dunes 5-30	10-25	18 S, 96% fn gr	16 S, 96% fn gr	
481	B-4 Al-4 Al-4-B-4	5-40 where bluff	35 where bluff	5-33 (100 one point) S, 10-95% fn gr,med gr cs gr, cobs mud	18-100 S, 10-92% med gr,cs gr cobs, bldrs	
482	Dh-C Dh-Cb Dlb Dl-Cb B-4-Cb	Dunes 5-4	Dunes 10-25	3-70 S, 85-100% fn gr,med gr	12-77 S, 70-100% fn gr,cs gr cobs, bldrs	
483	Ah-1 Ah-5-Cb Ah-4/1 Ah-1/5	35-250	35-45	7-45 S, 5-98% cs gr, cobs bldrs	17-56 S, 10-99% fn gr,med gr cs gr, dobs bldrs	

Physiographic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
484	Al-4	15	40-45	none	25 S, 95% cs gr, cobs bldrs	
485	Dl-C Dh-Cb	Dunes 6-60 Nip 5	Nip 30	20-35 S, 97-100% fn gr	17-38 S, 97-99% fn gr, mud bldrs	
485A	Ah-4/1	75	30	24 S a few bldrs	16 S, 96% fn gr	
486	Dl-Cb Dlb Dhb/Al-4	Dunes 20-85 Bluff 20-30 Nip 5	Bluff 15-20	15-63 S, 85-98% med gr,cs gr cobs	30-48 S, 88-96% fn gr,med gr cobs	
487	Ah-1 Ah-1,4,5	150-200	35-75	12-48 S, 10-97% fn gr,cs gr cobs, bldrs mud	14-29 S, 10-85% fn gr,med gr cs gr, bldrs	
488	B-4-Cb Al-4-B-4	Bluff 8-10 Dunes 15-20	10-30, nip	8-38 S, 98-100% fn gr	27-50 S, 96-99% fn gr	
489	Dl-Cb Dlb/Ah-4	Bluff 35-60 Dunes 15-40	Bluff 35	4-18 S, 30-99% fn gr,cs gr	24-56 S, 40-99% fn gr,cs gr bldrs	
490	Ah-1/4 Ah-1/2/1/4	30-200	40-50	0-10 S, 10% cs gr, cobs bldrs	13-27 S, 10-40% cs gr, cobs bldrs	
490A	Al-4/1-Cb	Bluff 20 Dunes 5	30	21 S, 95% med gr	35 S, 92% med gr	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
491	Ah-4-Cb	25-30	30	22 S, 96% fn gr	43 S, 97% fn gr	
492	Ah-Dl-C	Bluff est. 40 Dunes 8-30	10-30	21 S	44 S, 97% fn gr	
493A	Dl-C Dh-C Dl-B-4-C B-4	Dunes 3-50 Nip 3-15	10-30	8-75 S, 65-100% fn gr,med gr cs gr	18-59 S, 40-100% fn gr,med gr cs gr	
493	Ah-1 Ah-4 Ah-1-Dhb Al-4	50-375 (Al, 18 Ft.)	30-90	0-42 S, 65-99% fn gr, cs gr	16-36 S, 15-98% fn gr,cs gr cobs, bldrs	
494	Ah-1-C Ah-1-Dl-Cb	Bluff 45-175 Dunes 10-20	35	12-41 S, 99% fn gr	20-36 S, 99% fn gr	
495	B-4	---	---	31 S, 99% cs gr	31-40 S, 82-99% fn gr	
496	Dl-C	Dunes 15-35	Dunes 10-20 no nip	30-75 S, 97-99% fn gr	22-36 S, 93-97% fn gr,med gr	
497	B-4	---	---	19-34 S, 93-97% med gr,cs gr	53-57 S, 95-98% fn gr,cs gr	
498	Dhb-B-4	Dunes 40-60	no nip	96 S, 60% cs gr	40 S, 60% cs gr	
499	Ah-4 Ah-4-Dh Dl/Ah-4	Bluff 25-500	34-35	0-20 S, 98% fn gr	16-27 S, 82-90%	

Physiographic unit number	Basic coast zone elements	Height (ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
500	B-4-Cb-E	Dunes 15-25 Nip 6-10	35-40	35 S	30 S, 98% fn gr	
501	Dhb Dlb-E	Dunes 15-90 Bluff 10-75	33-35	37-40 S	26-48 S, 98% fn gr	
502	B-4	——	——	22 S	22 S, 96% fn gr	
503	Dh/Al-4 Ah-1	Bluff 275-375	32-35	none	15-32 S, 65-85% fn gr, cs gr bldrs	
504	Dl-Cb	Dunes 10-40 Nip 8	——	none	57 S	
505	Dh-Cb	Dunes 10-45 Nip 10	——	Narrow sand beach.		
506	Dl-Cb	Dunes 15-50 Nip 10	——	45 S, 80-85% med gr	72 S, 95% med gr	
507	Dlb	Dunes 30-40 Bluff 25	30	21 S	75 S	
508	Dh-C	Dunes 20-70	——	Beach zone of sand 50-60 feet wide.		
509	Ah-1-Dh-Cb	Bluff 125-150 Dunes 15-60	20-35	54 S, 40% med gr, cs gr	27 S, 65% med gr, fn gr	
510	Ah-1/4-Cb	Bluff 100-250 Dunes 15-60 Nip 10-15	Bluff 30-40	15-57 S, 70-85% fn gr, cs gr	23-40 S, 40-90% fn gr, med gr	

Physiographic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
511	Dh-Cb Al-4-Dhb	Bluff 10-50 Dunes 15-90	35	20-24 S, 70-99% med gr	25 S, 50-95% fn gr, med gr	
512	Ah-3/4 Ah-4/1/4	200-350	30-35	0-32 S, clay	18-21 S, 92-100% fn gr	
513	Al-Cb	Dunes 10-20 Nip 3-8	25-30	18 S	36 S	
514	Dh/Ah-4/1-Cb	Bluff 50-200	25-35	25-45 S	25-72 S	Figure 2
515	Ah-1/4 Ah-1/4/1	75-330	30	0-50 S	15-51 S, 97-100% fn gr	
516	Dh-Cb Dhb	Dunes 50-90 Foredunes 10-35 Nip 4-12	30-32	16-70 S	22-40 S, 92-100% fn gr	
516A	Ah-4	290-300	34-40	18-21 S, 80-99% fn gr, cs gr	28-30 S, 65-92% fn gr, med gr	
517	B-4-Cb Dl-Cb	Dunes 15-40 Nip 5-12	30	12-27 S, 96-100% fn gr	18-24 S, 65-100% med gr	
518	E-Cb	Dunes 10-20	—	30-42 S, 75-100% fn gr		
520	Ah-1 Ah-4/1 Ah-1/4	50-150	34	0-36 S	22-45 S, 65-95% fn gr	
521	B-1-Cb	Dunes 6-10 Nip 5	30	12 S	40 S, 96% fn gr	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
522	Ah-4	275-350	35	0-10 S, 95% fn gr	10-35 S, 50-99% cs gr, bldrs	
523	Dlb Dhb-Cb	Dunes 10-75 Bluff 6-40	25-30	20-25 S	30-65 S	
524	B-4-Cb	Dunes 10-15	---	none	32 S	
525	Ah-4 Ah-1/4-Cb	45-125	32-35	0-48 S, 96-100% cobs, fn gr	27-45 S, 95-98% fn gr	
526	Dhb Dlb	Dunes 20-110 Nip 10-40	35	10-40 S	27-50 S, 93-100% fn gr	
527	Ed-Cb	Dunes 10-15	30	21 S	30 S, 95% fn gr	
528	Ah-1,5,4 Ah-4/1 Ah-1-Cb	50-120	30-50	0-24 S	8-48 S, 0-100% fn gr, cobs bldrs	
529	Dhb	Dunes 40 plus	32	Sandy beach zone.		
530	Cb Dh-Cb	Dunes 10-50 Nip 4-10	0-48 S	0-48 S	24-70 S, 97-100% fn gr	
531	Ah-1	110-125	35-90	none	20-60 S, 95% fn gr	
532	Ah-4-Cb	Bluff 40-60 Dunes 10-15	25-30	21-33 S, 95-100% fn gr	18 S, 92-95% fn gr	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
533	Dl-Cb Dhb-Cb	Dunes 10-60 Nip 6-10	35	40-60 S	45-48 S, 99% fn gr	
534	Ah-4/1 Ah-1/4	75-95	34-45	0-12 S, 90-96% fn gr	10-36 S, 90-96% fn gr	
535	Al-4	15	25	18 S, 95% fn gr	15 S, 95% fn gr	
536	Ah-4-Dh	Dunes 75-125 Nip 10	15-32	33 S	36 S, 88-90% fn gr	
537	Dl-Cb Dh-Cb	Dunes 20-150 Nip 15-18	30, Nip	25-75 S, 96-100% fn gr	40-72 S, 92-100 fn gr,med gr seawalls one area	
538	Al-4-C Dl/Al-4	Bluff 15-20 Dunes 6-8	——	0-75 S	35-75 S	
539	Ed-Cb	Dunes 20-25 Nip 5-12	20-30	0-40 S, 98% fn gr	30 S, 96-100% fn gr	
540	Ah-1 Ah-1/4 Ah-2/4/5 Ah-3/4	30-300	36-60	0-30 S, 90-100% fn gr,med gr	12-40 S, 50-97% fn gr,med gr cob gr,bldrs	
541	Dh-Cb Dhb-Cb	Dunes 20-150 Nip 10-55	Nip 25-34	0-60 S	25-75 S	
542	B-4-Cb	Dunes 25-35 Nip 10-20	30	30 S	90 S	

Physiographic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
543	Dh-Cb	Dunes 20-100 Nip 10-15	30	40 S	55 S	
544	Dhb-Cb	Dunes 15-125 Nip 8-15	30	35 S	45 S	
545	Ah-1-Cb	Bluff 50-100	30	none	60-85 S	
546	Dhb Dh-Cb Dlb	Dunes 40-125 Nip 4-35	35	0-45 S	35-115 S	
547	Al-1-Dh-Cb	Bluff 185 Dunes 30-100	30	none	30-35 S	
548	Dh-Cb Dhb-C	Dunes 15-150 Nip 10-20	30	0-20 S	20-75 S	
549	Ah-1-Cb Ah-2 Ah-1/2-Cb	60-200	35	none	35-90 S	
550	Dh-Cb Dhb	Dunes 15-125	30	0-30 S	50-115 S	
551	Ah-4 Ah-4-C	55-95	36-40	0-15 S	0-75 S	
552	Dh/Ah-4	Dunes 100-125 Bluff 20-75	35	none	0-108 S	
553	Dh-Cb	Dunes 15-50 Nip 5-15	30	25-35 S	25-95 S	
554	Dhb	Dunes 75 Bluff 60	37	none	0-30 S	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
555	E-Cb	Dunes low	---	Sandy beach zone.		
556	Dh/Ah-4 Dhb	Dunes 175 Bluff 35	35	10 S	35 S	
557	Ah-4	12-50	33-37	0-30 S	20-50 S	
558	Dhb	Dunes 75-100 Bluff 40-75	30	none	45-75 S	
559	Dhb-R			20 ft. beach behind groins and seawall.		
560	Dl-Cb Dhb	Dunes 10-25 Nip 4-15	30	0-55 S One area: seawall.	30-60 S	
561	Dhb	Dunes 50-100 Bluff 30-40	30	Beach zone 40-50 ft. wide of sand. Local seawalls and jetties. Beach 60-150 ft. wide near breakwater.		
562	Dhb-Cb	Dunes 20-50 Nip 8-10	30	70 S	60 S	
563	Dhb	Dunes 40-100 Bluff 5-40	30	0-40 S	20-65 S	
564	Dh-Cb Dhb-Cb	Dunes 15-75 Nip 10-18	30	0-40 S	33-45 S	
565	Dhb	Dunes 40-70 Bluff 20-30	30	Sandy beach zone.		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
566	B-4-Cb Dhb-Cb	Dunes 20-60 Nip 10-12	30 where nip	25 S	35 S	
567	Dhb	Dunes 40-60	30	Sandy beach zone.		
568	Dl/Ah-4/1 Dl/Ah-4/2	Bluff 40-45	30-40	none	5-60 S	
569	Dhb Cb	Dunes 20-60 Nip 8-10	30	25 S	50 S	
570	Dhb	Dunes 40-60	30	Sandy beach zone		
571	Dh-Cb	Dunes 25-60 Nip 10-15	30	25 S	25 S	
572	Dhb	75-100	31	none	35 S	
573	Dhb-Cb	Dunes 25-60	30	none	42 S	
574	Dhb	Bluff 20-50	35	42-50 S	45-75 S	
575	Dl/Ah-4	Bluff 55	32	10-15 S	0-3 S	
576	Dh-Cb	Dunes 15-80 Nip 10-15	30	25 S	45-50 S	
577	Dl/Ah-4-Cb Dl/Ah-4	Bluff 45-50	30	25 S	45-105 S	
578	Ah-4	25	30	20-25 S	30-35 S	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
579	Dh/Ah-4	Dunes 40-75 Bluff 25	30	none	50 S	
580	Dhb	Dunes 40-60	30	Sandy beach zone.		
581	Dhb-Cb	Dunes 20-200 Nip 10	30	30-40 S	60-75 S	
582	Dhb	100-255	33	none	35-40 S	
583	Dh-Cb	15-100	30	20 S	33 S	
584	Dl-Cb	Dunes 10-30 Nip 5-10	30	Sandy beach zone		
585	Dh-Cb	Dunes 25-60 Nip 20-25	30	none	50 S	
586	Ah-1	50-71	45-90	none	8-80 S, 25-98% med gr, cs gr cobs, bldrs	
587	Dl/Ah-1/4 Dh/Ah-1-Cb	Dunes 20-4 Bluff 6-33	45-70	0-20 S	45-80 S, 98-100% cobs, fn gr	
588	Ah-1 Ah-1/4 Ah-4-Cb	Bluff 40-125	35-90	0-35 S, 98-100% silt, cobs	25-168 S, 40-100% fn gr, med gr cobs	
589	B-4-C B-4-Cb	Dunes 12-15	30	45 S	84 S	
590	Ah-R	40	35	No beach — steel seawall. Bluff in artificial fill.		
591	Ah-1	50-55	50-60	No beaches.		

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
592	Dl/Ah-4	40-48	43	none	30-55 S, 96-99% fn gr,cobs	
593	Ah-4/5	30	45-60	none	40-45 S	
594	Dh-Cb Dhb	Dunes 10-200 Nip 5-12	30	0-30 S	20-90 S, 60-100% fn gr	Figure 13 Figure 14
595	Ah-1 Ah-1/4/5	90-140	40-49	none	40-95 S	
596	B-4-Cb	Dunes 25 Nip 6	30	35 S	72 S, 95-97% fn gr	
597	Ah-Dl-C	Bluff 20-30 Dunes 5-10	Bluff 20	Wide sandy beach held by groins and long harbor seawall.		
598	Ah-R	10-30	30-40	Artificial fill and seawall.		
599	Ah-4 Ah-1/5,4	60-95	35-45	0-40 S, 99% fn gr seawall, in part	15-66 S, 98% fn gr,clay	
600	Dhb	Bluff 30-50	30	20 S	40 S	
601	Dlb	20-40	30	30 S	70 S	
602	Dhb	Dunes 40-125 Bluff 10-30	36	20-40 S	45-70 S	
603	Dhb-Cb Dh-Cb Dl-Cb	Dunes 20-125 Nip 5-10	30	0-50 S	30-110 S, 98-100% fn gr	

Physio-graphic unit number	Basic coast zone elements	Height(ft.) bluff, cliff or dune	Slope in degrees, bluff or cliff	Backshore: width in ft.; materials	Foreshore: width in ft.; materials	Photo number
604	Ah-1 Ah-1-Cb Ah-3	20-60	35-50	0-30 S, clay	40-100 S, 95-98% fn gr, clay	
605	Dhb	Dunes 40-50 Bluff 20-25	30-35	30 S	45 S, 95-100% med gr	
606	B-6-Cb	Dunes 20-30 Nip 5-10	29	none	93-108 S, 90-99% fn gr	
607	Dhb Dhb-Cb Dlb	Dunes 10-130 Bluff 10-110	24-40	0-91 S, 92-100% fn gr	42-148 S, 65-99% fn gr, clay	Figure 15
608	Dl-C	Dunes 10-25	----	Narrow S	120 S, 95% fn gr	
609	Dlb-C Dl-C	Dunes 15-40 Bluff 10-15	30	40-100 S	87-125 S, 96-100% fn gr	

Figure 1. Ah-1/-4/1. Bluff 55-60 feet high of till, over lacustrine sand and gravel, over till. Fresh steep slope indicates recent wave erosion. Narrow beach of sand and coarse gravel. Physiographic Unit No. 54.

Figure 2. Dh/Ah-4/1-Cb. Old bluff on left 175-200 feet high including capping of high dunes. Belt of foredunes 10-15 feet high, with nip 6-8 feet high. Sandy beach. Physiographic Unit No. 514.

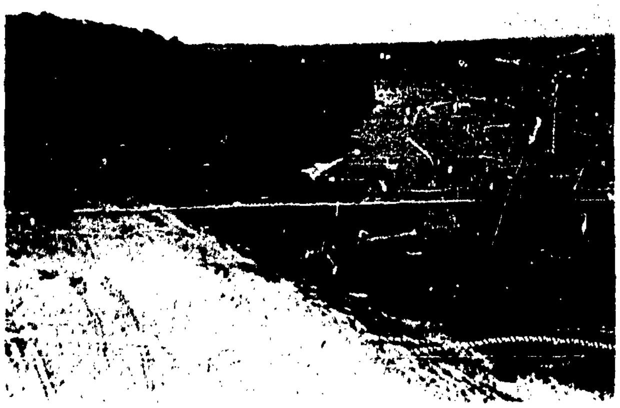


Figure 3. Ah-2/5/4-Al-4. Old bluff at left 130 feet high; lower plain at right and in middle distance has bluff 15-20 feet high. Higher bluff is of glacial sand and gravel, over lacustrine clay and silt, over lacustrine sand and gravel; low bluff is of lacustrine sand and gravel. Narrow beach of sand, gravel, and cobbles. Physiographic Unit No. 463.

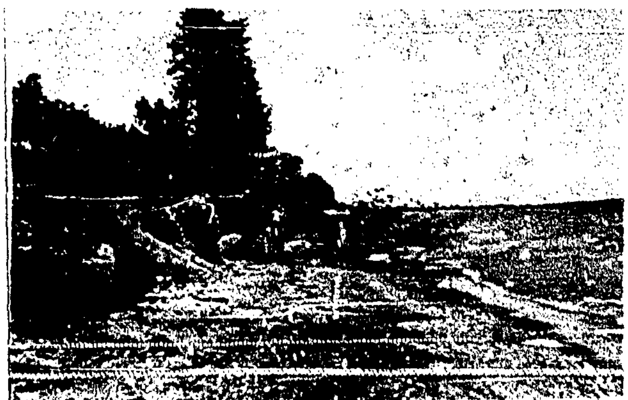


Figure 4. Al-1. Bluff of till 13-14 feet high. Beach of sand, gravel, and boulders. Fresh slope and fallen tree indicate rapid wave erosion.
Physiographic Unit No. 42.

Figure 5. Al-5. Bluff 15 feet high of lacustrine silt and clay. Beach of sand. Fresh bluff face and overhanging sod indicate rapid wave erosion.
Physiographic Unit No. 42.

Figure 6. B-4. Low wooded plain of lacustrine sand and gravel. Broad beach of sand and a few boulders, which may come from till below. Beach appears to be aggrading.
Physiographic Unit No. 209.

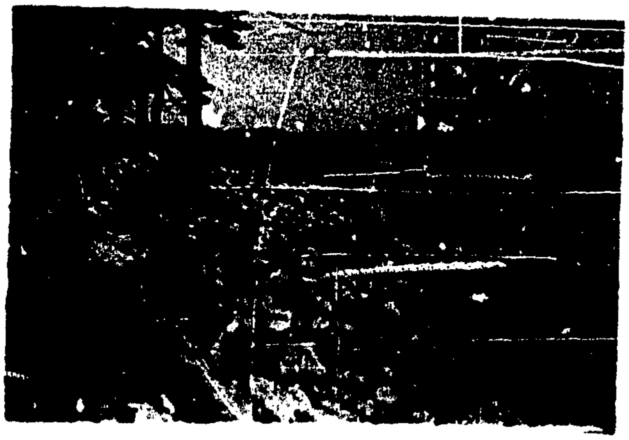


Figure 7. B-4. Low plain of bouldery lacustrine gravel, with boulder and cobble beach. Undermined trees show that wave erosion is taking place.
Physiographic Unit No. 195.

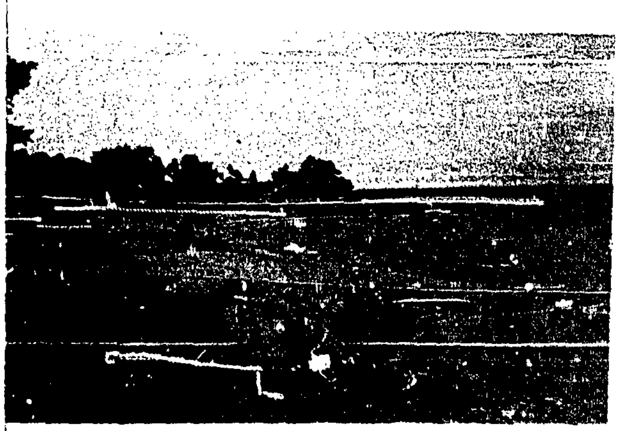


Figure 8. B-4. Low plain of lacustrine sand and gravel with broad sandy beach. House stands on estate held by boulder sea wall, that now projects 135 feet into lake beyond water line on north and south. House was built in 1938, and seawall was built in 1950. Active wave erosion between 1950 and 1956 is indicated.
Physiographic Unit No. 1.

Figure 9. B-4-r. Low plain of coarse lacustrine gravel (shows at right) overlying slabby dolomite bedrock which forms bench in beach zone. Bench strewn with blocks and slabs. Physiographic Unit No. 138.

Figure 10. B-4-r. Low plain of coarse lacustrine gravel and sand (exposed at right). Narrow beach zone of gravel, cobbles, boulders, and dolomite slabs. Dolomite bedrock is exposed near this area and is inferred here. Physiographic Unit No. 69.

Figure 11. B-4-Cb-r. Low wooded plain of lacustrine sand and gravel, with marginal belt 75-90 yards wide of foredunes 8-15 feet high. Nip 10 feet high. Beach of sand, coarse gravel, and angular shingle. Bedrock reef inferred. Physiographic Unit No. 305.

Figure 12. Dh-Cb. Wooded dunes in right distance 50-55 feet high. Belt 100-200 feet wide of foredunes 10-30 feet high, with low nip above broad sand beach. Small river on right lies back of foredunes. Physiographic Unit No. 334.

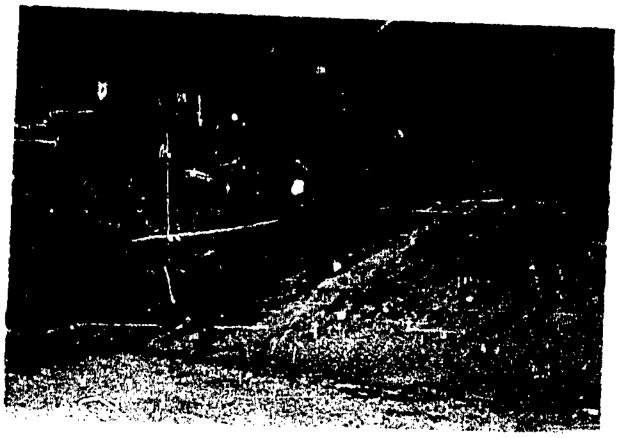


Figure 13. Dhb. Dunes 120-140 feet high; dune sand rests on 15 feet of lacustrine sand and gravel at base of bluff. Fresh bluff indicates recent active wave erosion. Narrow sandy beach.
Physiographic Unit No. 594.

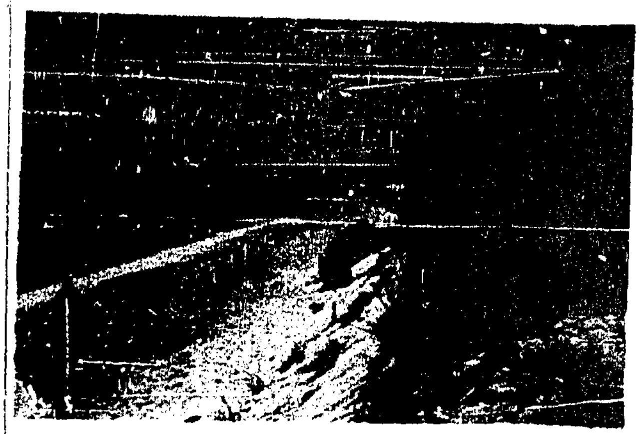


Figure 14. Dh-Cb.Wooded dunes at right 130 feet high. Foredunes (foreground) 15-20 feet high, with 6-8 foot nip. Beach zone of sand and gravel. Recent erosion is indicated.
Physiographic Unit No. 594.

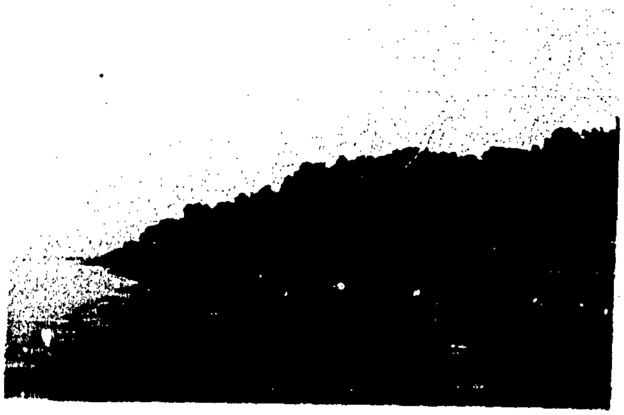


Figure 15. Dlb. Dunes about 35 feet high, with wave-eroded bluff 20-25 feet high. Broad beach of sand and fine gravel.
Physiographic Unit No. 607.

Figure 16. Dlb/B-4. Dunes 15-25 feet high rest on plain of lacustrine sand and gravel 12-14 feet above lake level. Fresh bluff on dunes shows wave erosion in recent years. Broad beach of sand and pebbles.
Physiographic Unit No. 48.

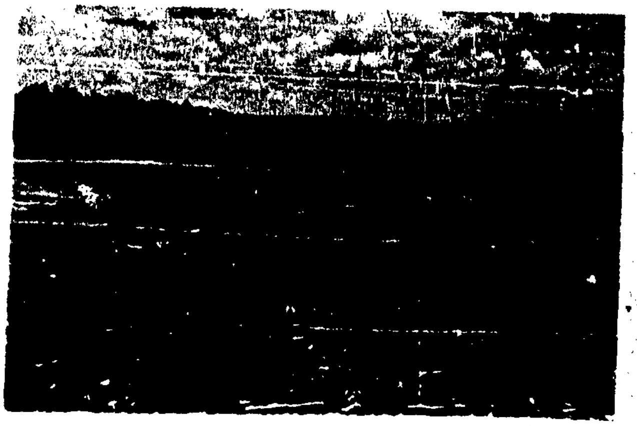


Figure 17. Dl-r. Low wooded dunes (left background) with very broad beach mainly of sawdust and driftwood with about 20% sand. Rock reefs near water line defend beach at places. Physiographic Unit No. 329.

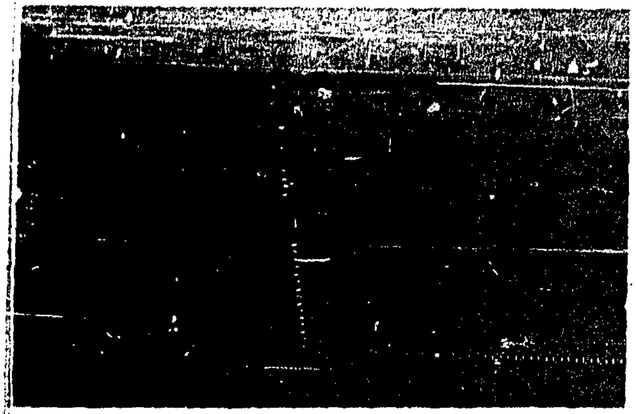


Figure 18. Dl-B-4. Gravel bar enclosing lagoon. At left beyond view is gravel foreland or plain in front of low dunes. Physiographic Unit No. 428.

Figure 19. Fh. Vertical cliff of dolomite 35-45 feet high. Narrow beach zone of angular slabs, blocks and shingle.
Physiographic Unit No. 114.

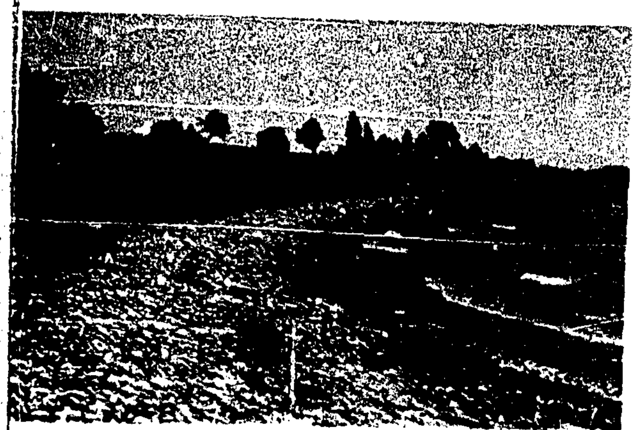


Figure 20. Fh-B-4. Cliff of shaly dolomite and limestone, 30-35 feet high. At left is low gravel foreland 6-8 feet above lake. Beach is of angular shingle and slabs.
Physiographic Unit No. 249.

Figure 21. Fl. Plain of dolomite about 18 feet above water, with vertical cliff 12-15 feet high. No beach zone.
Physiographic Unit No. 149.

Fl-r
Figure 22./ Plain of dolomite about 18 feet above water. Vertical cliff about 14 feet high. Narrow beach zone of cobbles and small boulders.
Physiographic Unit No. 149.

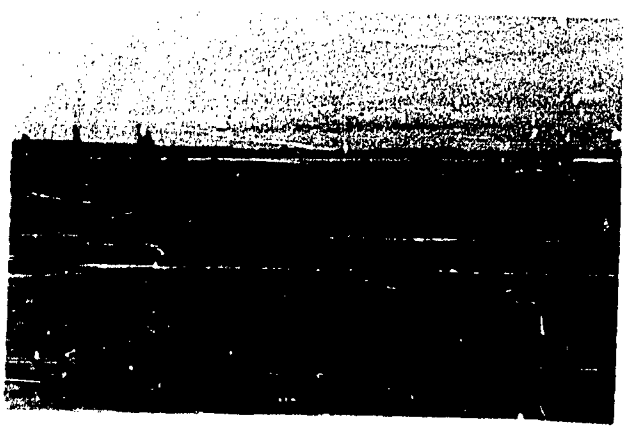


Figure 23. B-4-r-M. Beach and offshore zone of low plain of lacustrine sand and gravel. Beach zone of sand, coarse gravel, and slabs. Reefs of dolomite show through beach deposits at places. Offshore zone 50-300 yards wide is filled with reeds.
Physiographic Unit No. 396.

Figure 24. Ah-4. Margin of a plain of lacustrine sand and gravel 25-30 feet above lake. Road rests on fill stabilized by grass and protected at base from waves by riprap ridge.
Physiographic Unit No. 235.

PRESENT AND PAST CHANGES IN THE SHORE ZONE

Shore Processes — Progradation and Retrogradation

Along most of the Lake Michigan shore zone, wave and current action has either built out (prograded) or cut back (retrograded) the land. These processes have been slow or rapid, depending on a number of factors. In general, erosion seems to have been most common. Deposition or progradation occurs where a large amount of sediment is supplied to the shore by tributary streams or shore erosion nearby, or where a large amount of sediment in longshore transit is caught by some projecting point or structure. No large amounts of sediment are being brought into Lake Michigan by tributary streams. Where man has built long piers, groins, or other structures out from the shore, these have locally caught longshore drift so as to create beaches up to several hundred feet wide. At a few places the configuration of the shoreline has led to a concentration of longshore drift at certain points — notably at Point Betsie in Benzie County, and Big Sable Point in Mason County, Michigan. But at most places the shore is relatively stable or has suffered recession. The rate of such recession depends on such factors as the following:

Height of backland above mean lake level.

Materials composing backland and landface, whether weak or strong.

Abundance and coarseness of beach materials, whether moved in from elsewhere or derived from the retreating landface by erosion and assorted by wave action.

Exposure to lake storms and waves. The inner shores of bays suffer feebler wave attack than headlands or straight stretches of shore.

Protective structures built by man.

Level of Lake Michigan. During periods of high average lake level, wave attack is several times more vigorous than during periods of low average level.

Unusual storms of great severity.

The factors which vary most strongly with respect to time are the two last named. The mean monthly level has shown extremes, since 1854, of 577.2 feet in February, 1933, and 583.8 feet in July, 1859. From 1900 to 1953 the level averaged 579.9 feet, with unusually high levels occurring in 1918, 1929, and the period 1943 to 1952. Unusually low levels occurred in 1926 and 1934. Without exception, accelerated shore erosion has taken place during times of high water, while during low water, beaches have widened and wave attack on the landface has been much less effective. Records kept since 1854 show that lake levels have fluctuated in an irregular pattern with times of high water recurring, on the average, every ten to twelve years. Past wave erosion has varied with these changes in lake levels.

The problem of present wave erosion and shore retreat is a very serious one to both municipalities and individuals. As such, it has been persistently studied by engineers and engineering organizations, including the Beach Erosion Board of the U.S. Army, Corps of Engineers. The latter organization has published the results of detailed shore studies in Milwaukee and Racine Counties, Wisconsin; the city of Kenosha; and Lake and Cook Counties, Illinois. A similar report on Berrien County, Michigan, is now ready. To these reports the reader is referred for information on engineering aspects of the shore problem.

Former Studies of Shoreline Changes

The problem of Lake Michigan shore recession under wave attack was studied as early as 1864 by Charles Whittlesey in the Milwaukee area, and 1868 and 1870 by Henry M. Bannister in Illinois. Although neither gave quantitative measurements, both authorities concluded that past wear of bluffs may have amounted to hundreds of feet and that the annual rate was several feet at

many places. In 1870 Edmund Andrews* computed that, in a period of 15 to 35

* Andrews, Edmund, "The North American Lakes Considered as Chronometers of Post-Glacial Time," Trans. Chicago Acad. Sci., Vol. II, 1870, pp. 1-24.

years preceding 1870, annual recession of the shore averaged 5.28 feet at 23 selected points between Evanston and Manitowoc. T. C. Chamberlin in 1877 published results of computations by P. R. Hoy, S. G. Knight, and himself.**

** Chamberlin, T. C., "Geology of Wisconsin," Vol. II, 1877, pp. 219-233.

Hoy found that Racine cemetery suffered an average annual loss, between 1840 and 1884, of 9.73 feet per year. Knight found that between 1836 and 1874, the average recession at 18 section and quarter-section lines in Racine County was 3.33 feet annually. Chamberlin computed that the average annual loss at 8 section lines in Milwaukee County, between 1835 and 1874, was 2.79 feet. Frank Leverett in 1899*** published results of measurements made by Surveyor

*** Leverett, Frank, "The Illinois Glacial Lobe," U.S.G.S. Mon. XXXVIII, 1899, p. 458.

Galvin of Berrien County, Michigan, which indicated an average annual loss, at 8 points in that county during the 41 to 57 years following 1828, of 3.30 feet.

Between 1905 and 1907, the low bluff in lacustrine clay and silt at Manitowoc, Wisconsin, suffered an annual recession of more than 40 feet, according to J. W. Goldthwait.**** W. E. O'Brien found that 6 section and quarter

**** Goldthwait, James W., "Abandoned Shorelines of Eastern Wisconsin." Wis. Geol. and Nat. Hist. Surv., Bull. 17, 1907, p. 58.

section lines in Kenosha County, Wisconsin, showed an average annual loss of 6.84 feet between 1835 and 1922.* J. R. Ball found that 4 measured lines

* Ball, J. R., and Powers, W. E., Shore Recession in Southeastern Wisconsin: Trans. Ill. Acad. Science, Vol. 22, 1930, p. 438.

north of Kenosha showed an average annual recession for the period 1918-1921, a time of high water, of 12.33 feet per year.** At the same place the loss

** Ball and Powers, Idem. p. 439.

between 1921 and 1929, a period of generally low water, averaged only 0.73 feet per year.

More recent studies have confirmed the fact of substantial losses to the shore. In four segments along the Milwaukee County line, the Beach Erosion Board computed the average annual losses between 1836 and 1941 to be, from north to south, 2.5 feet, 1.6 feet, 2.8 feet, and 1.2 feet.*** The Beach

*** U. S. Army, Corps of Engineers, Beach Erosion Board, Beach Erosion Study, Lake Michigan Shore Line of Milwaukee County, Wisconsin: U.S. House of Representatives, 79th Congress, 2nd Session, 1946, Document No. 526, p. 13.

Erosion Board determined that bluff recession averaged about 2 feet per year north of the harbor in Kenosha, and about 4 feet south of the harbor, between 1872 and 1955.****

**** U.S. Army, Corps of Engineers, Beach Erosion Board, City of Kenosha, Wisconsin, Beach Erosion Control Study: House of Representatives, 84th Congress, 2nd Session, 1955, Document No. 273, p. 11

In Illinois, the past history of the shoreline from Wilmette and northward to the Wisconsin line shows contradictions because (1) part of this shore is a low lake plain of natural accretion, and (2) much of the shore here has

been developed since 1910 with protective structures which have promoted accretion, even though erosion had been dominant previously.* The low lake

* U. S. Army, Corps of Engineers, Beach Erosion Board, Illinois Shore of Lake Michigan, Beach Erosion Control Study: House of Representatives, 83d Congress, 1st Session, 1953, Document No. 28, pp. 30-31.

plain near Camp Logan and the Wisconsin line suffered erosion losses averaging 7.5 feet per year between 1872 and 1946. In Waukegan, the same lake plain, during the same period, showed an average annual accretion of 17.6 feet! Part of this gain may have been fill placed by man. Behavior of the coastline south of Waukegan shows similar contradictions, although losses of from 1 to nearly 6 feet per year occurred at certain points between 1872 and 1910. At some places, the process changed from recession to accretion after 1910, due to development of the shore.

Remeasurements to the Lake Michigan Shore at Identifiable Points

A part of the present study is an attempt to evaluate past changes in the shoreline at places other than those studied by the Beach Erosion Board. Early basic measurements were furnished by (a) the original U. S. government township surveys, dating from the 1830's for most of the Lake Michigan shore area, but with some notes dated from 1829 to 1855; and (b) surveyed plats of shore subdivisions dating mainly from 1900 to 1930, but with a few earlier and later. No surveyed plat was used of later date than 1837.

Field notes made during the original U. S. government township surveys record the distances from section and quarter posts to the "meander line" of the lake. The "meander line" was never precisely defined, but clearly it was seldom, if ever, identified with the water line. In many cases the measurements were obviously made to some point at or near the edge of the

bluff, where present. Our resurveys were carried in every case to the edge of the bluff, and thus our computed recession must be somewhat less than the actual, wherever the original meander line was inland from the bluff edge. The pattern of roads and field boundaries on aerial photos shows many section and quarter corners. All of these that could be identified within 1/2 mile to 1 mile of the lake were tabulated, and their original chained distances to the meander line of the lake were procured from copies of the original field notes filed in state offices in Madison, Wisconsin; Lansing, Michigan; and Indianapolis, Indiana. Where possible, these distances were remeasured in the field, either with a steel tape or by stadia measurement with a telescopic alidade. Tests of the latter method indicated a probable error of no more than 0.5%, a value on most lines far smaller than the change in position of the shore or meander line. In no case was an original corner or quarter post recovered, but the position of long established fence lines and other boundary indications checked closely with the chained distances given in the original survey. It is believed that most if not all points of origin used for remeasurement were correct to within 3 to 5 feet of their true position.

A considerable number of surveyed subdivision plats were obtained from county engineers and recorders of deeds. The courtesy and assistance of Messrs. H. E. Stafseth and William Osner of the Highway Commission of Ottawa County, Michigan is gratefully acknowledged. Many of these plats gave distances to the waterline rather than to bluffs or other features above the beach zone. Inasmuch as position of the waterline changes, without erosion of or accretion to the shore, by any change in water level, such measurements are less satisfactory than those to a bluff crest which can change only by further recession. In some of the older subdivision plats, it proved impossible

in the field to recover the original street pattern and other reference points. Some of the projects had been abandoned; in others, a second and different subdivision plan had been superimposed on the first. However, approximately 20 remeasurements were established from these plats and are included in Table III.

A summary of the results of remeasurements at 134 selected points along the Lake Michigan shoreline is given in Table III. For each point is listed the location, date of original survey, gain or loss in feet up to the year 1957, and average change per year in feet. Of the 134 points or stations, six showed net gain or accretion, generally small but amounting in one case to 5.86 feet per year between 1902 and 1957. Four stations showed no change during the period of record. One hundred twenty-four stations showed recession, averaging 1.47 foot per year. The greatest loss, 3.40 feet per year since 1835-36, was recorded in Kenosha County. Thirty-four stations showed an average annual loss of more than 2 feet, and 36, a loss of between 1 and 2 feet. Only 13 stations showed a total loss of more than 300 feet during the period of record. For these and similar details, the reader is referred to Table III.

The total recession and its average annual rate as determined for these 134 stations are both smaller than would be expected from most of the earlier studies reviewed under "Former Studies of Shoreline Changes" above. It is apparent that such men as Chamberlin, Hoy and Goldthwait considered only shore segments of unusually severe erosion.

Table III. Summary of Past Erosion or Accretion at 134 Selected Points on the Lake Michigan Shore

No.	County	Tier	Range	Sec.	Description	Date Orig. Survey	Gain(+) or loss (—) in feet to 1956-57	Change Per Year
1	Kenosha	1 N	23 E	32	NW Corner	1835-6	1016-	8.40-
2	Kenosha	1 N	23 E	7	NE Corner	1835-6	512-	4.23-
3	Kenosha	2 N	23 E	31	NE Corner	1835-6	23+	0.19+
4	Kenosha	2 N	23 E	5	SW Corner	1835-6	297-	2.45-
5	Kenosha	2 N	23 E	5	NW Corner	1835-6	460-	3.80-
6	Racine	3 N	23 E	4	N ¼ Post	1850	136-	1.12-
6A	Racine	4 N	23 E	34	N of W ¼ Post	1926	40-	1.33-
7	Racine	4 N	23 E	27	SW Corner	1835-6	186-	1.54-
8	Racine	4 N	23 E	17	E ¼ Post	1835-6	142-	1.17-
9	Racine	4 N	23 E	7	N ¼ Post	1835-6	422-	3.49-
9A	Ozaukee	9 N	22 E	33	SE ¼	1900	35-	0.61-
9B	Ozaukee	9 N	22 E	28	NW ¼	1926	0	0
10	Ozaukee	9 N	22 E	29	NE Corner	1833-4	279-	2.27-
11	Ozaukee	9 N	22 E	8	S ¼ Post	1833-5	353-	2.89-
12	Ozaukee	9 N	22 E	5	S ¼ Post	1833-5	372-	3.05-
13	Ozaukee	10 N	22 E	32	NE Corner	1833-5	416-	3.41-
14	Ozaukee	10 N	22 E	16	NE Corner	1833-5	203-	1.66-
15	Ozaukee	10 N	22 E	3	SW Corner	1833-5	206-	1.69-
16	Ozaukee	11 N	22 E	2	S ¼ Post	1833-5	156-	1.28-
17	Ozaukee	12 N	23 E	30	NW Corner	1833-5	1-	0.01-
18	Ozaukee	12 N	22 E	25	S ¼ Post	1833-5	14-	0.11-

No.	County	Tier	Range	Sec.	Description	Date Orig. Survey	Gain(+) or loss (—) in feet to 1956-57	Change Per Year
19	Ozaukee	12 N	23 E	7	SW Corner	1833-5	14-	0.11-
20	Ozaukee	12 N	23 E	6	NW Corner	1833-5	2-	0.02-
21	Sheboygan	13 N	23 E	19	NE Corner	1834-5	49-	0.40-
22	Sheboygan	13 N	23 E	30	SW Corner	1834-5	52+	0.42+
23	Sheboygan	13 N	23 E	5	SE Corner	1834-5	67-	0.55-
24	Sheboygan	14 N	23 E	15	SE Corner	1834-5	69-	0.57-
25	Sheboygan	14 N	23 E	2	S ¼ Post	1834-5	145-	1.19-
25A	Sheboygan	15 N	23 E	35	NE ¼ "	1891	67-	1.02
25B	Sheboygan	15 N	23 E	11	SE ¼	1926	0	0
26	Sheboygan	16 N	23 E	34	S ¼ Post	1834-5	203-	1.66-
27	Sheboygan	16 N	23 E	27	SW Corner	1834-5	117-	0.96-
28	Sheboygan	16 N	23 E	27	NW Corner	1834-5	138-	1.13-
29	Sheboygan	16 N	23 E	22	W 1/8 Post, N Line	1834-5	198-	1.62-
30	Sheboygan	16 N	23 E	15	W 1/8 Post, N Line	1834-5	115-	0.94-
31	Manitowoc	17 N	23 E	34	N ¼ Post	1834	168-	1.37-
31A	Manitowoc	17 N	23 E	27	NW ¼ " "	1856	74-	0.74-
31B	Manitowoc	17 N	23 E	27	N Line "	1866	24-	0.27-
32	Manitowoc	17 N	23 E	22	NE Corner	1834	55-	0.45-
33	Manitowoc	17 N	23 E	11	S ½ Post	1834	244-	1.98-
34	Manitowoc	17 N	23 E	2	NE Corner	1834	33-	0.27-
35	Manitowoc	18 N	23 E	24	E 1/8 Post N Line	1834	24-	0.20-
36	Manitowoc	18 N	24 E	7	Center	1834	245-	1.99-

No.	County	Tier	Range	Sec.	Description	Date Orig. Survey	Gain(—) or loss (—) in feet to 1956-57	Change Per Year
37	Manitowoc	18 N	24 E	5	NW Corner	1834	139-	1.13-
38	Manitowoc	19 N	24 E	16	NE Corner	1834	234-	1.90-
39	Manitowoc	21 N	25 E	30	SW Corner	1834	273-	2.22-
40	Manitowoc	21 N	24 E	24	NW Corner	1834	350-	2.85-
41	Manitowoc	21 N	24 E	24	S ¼ Post	1834	344-	2.79-
42	Manitowoc	21 N	24 E	2	S ¼ Post	1834	234-	1.90-
43	Manitowoc	21 N	24 E	2	N ¼ Post	1834	55-	0.45-
44	Kewaunee	22 N	24 E	36	W ¼ Post	1834-5	272-	2.23-
45	Kewaunee	22 N	24 E	13	E 1/8 Post, S Side	1834-5	205-	1.67-
46	Kewaunee	22 N	25 E	6	SW Corner	1834-5	52-	0.42-
47	Kewaunee	22 N	25 E	6	NW Corner	1834-5	57-	0.47-
48	Kewaunee	23 N	25 E	31	N ¼ Post	1834	77-	0.63-
48A	Kewaunee	23 N	25 E	20	NW ¼	1883	187+	2.56+
49	Kewaunee	23 N	25 E	8	SW Corner	1834	140-	1.14-
50	Kewaunee	23 N	25 E	8	N ¼ Post	1834	74-	0.60-
51	Kewaunee	24 N	25 E	28	NW Corner	1834	33-	0.27-
52	Kewaunee	24 N	25 E	16	SW Corner	1834	29-	0.24-
53	Kewaunee	24 N	25 E	16	N ¼ Post	1834	80-	0.65-
54	Kewaunee	24 N	25 E	3	W 1/8 Post, N Side	1834	10+	0.08+
55	Kewaunee	25 N	25 E	23	E 1/8 Post, S Side	1834-5	61-	0.50-
56	Door	26 N	26 E	21	SW Corner	1835	0	0

No.	County	Tier	Range	Sec.	Description	Date Orig. Survey	Gain(—) or loss (—) in feet to 1956-57	Change Per Year
57	Door	26 N	26 E	21	E 1/8 Post, N Side	1835	22-	0.18-
58	Door	26 N	26 E	4	S ¼ Post	1835	24-	0.20-
59	Door	26 N	23 E	21	S ¼ Post	1834	28-	0.23-
60	Door	26 N	23 E	16	NE Corner	1834	39-	0.32-
61	Door	26 N	23 E	28	S ¼ Post	1834	38-	0.31-
62	Door	26 N	23 E	32	E 1/8 Post, S Side	1834	114-	0.93-
63	Grand Traverse	28 N	10 W	31	SW Corner	1839	93-	0.79-
64	Grand Traverse	29 N	10 W	27	NE Corner	1839	19-	0.16-
65	Grand Traverse	30 N	10 W	33	NE Corner	1839	8-	0.07-
66	Grand Traverse	29 N	10 W	9	SW Corner	1839	37-	0.31-
67	Leelanau	29 N	11 W	2	W 1/8 Post S Side	1850	29-	0.27-
68	Leelanau	30 N	11 W	27	NE Corner	1851-2	0	0
69	Leelanau	32 N	10 W	17	SW Corner	1855	42+	0.41+
70	Leelanau	32 N	10 W	7	NE Corner	1855	32-	0.31-
71	Leelanau	31 N	11 W	7	NE Corner	1851	35-	0.33-
72	Leelanau	30 N	14 W	36	SE Corner	1839	42-	0.36-
73	Leelanau	29 N	14 W	12	W 1/8 Post, N Side	1839-50	398-	3.37-
74	Leelanau	28 N	15 W	24	E 1/8 Post, S Side	1850	256-	2.40-
75	Benzie	25 N	16 W	3	NE Corner	1838	70-	0.59-
76	Benzie	25 N	16 W	3	SE Corner	1838	382-	3.21-
77	Manistee	24 N	16 W	21	SE Corner	1838-9	96-	0.81-

No.	County	Tier	Range	Sec.	Description	Date Orig. Survey	Gain(—) or loss (—) in feet to 1956-57	Change Per Year
78	Manistee	23 N	16 W	29	SE Corner	1902	322+	5.86+
79	Manistee	22 N	17 W	25	NE Corner	1847	67-	0.61-
80	Manistee	21 N	17 W	14	NW Corner	1837-9	88-	0.75-
81	Manistee	21 N	17 W	22	E 1/8 Post, N Side	1837-9	68-	0.58-
82	Manistee	21 N	17 W	22	1/8 mi. S of E 1/8 Post, N Line	1923	54-	1.59-
83	Mason	18 N	18 W	10	SW Corner	1838	178-	1.50-
84	Mason	18 N	18 W	35	SW Corner	1838	34-	0.29-
85	Mason	17 N	18 W	14	NW Corner	1838	116-	0.97-
86	Oceana	15 N	18 W	5	SE Corner	1838	214-	1.80-
87	Muskegon	12 N	18 W	23	SW Corner	1837	218-	1.82-
88	Muskegon	12 N	18 W	23	E 1/8 Post, N Side	1837	128-	1.07-
89	Muskegon	11 N	17 W	31	NE Corner	1837	169-	1.41-
90	Muskegon	11 N	17 W	31	SE Corner	1837	94-	0.78-
91	Muskegon	10 N	17 W	8	NW Corner	1837	122-	1.02-
92	Muskegon	10 N	17 W	8	S $\frac{1}{4}$ Post	1837	231-	1.93-
93	Muskegon	9 N	17 W	24	NW Corner	1837	10-	0.08-
94	Ottawa	7 N	16 W	28	N $\frac{1}{4}$ Post	1832	95-	0.76-
95	Ottawa	6 N	16 W	4	S $\frac{1}{4}$ Post	1927	26-	0.87-
96	Ottawa	5 N	16 W	4	NE Corner	1832	100-	0.80-
97	Ottawa	6 N	16 W	33	N $\frac{1}{4}$ Post	1832	114-	0.91-
98	Ottawa	5 N	16 W	9	Point on N-S $\frac{1}{4}$ Line, 134 ft. S of N 1/8 Line	1932	80-	3.20-

No.	County	Tier	Range	Sec.	Description	Date Orig. Survey	Gain(—) or loss (—) in feet to 1956-57	Change Per Year
99	Ottawa	5 N	16 W	4	Center	1932	139-	5.56-
100	Ottawa	5 N	16 W	9	S $\frac{1}{4}$ Post	1832	4-	0.03-
101	Ottawa	5 N	16 W	16	S $\frac{1}{4}$ Post	1832	66-	0.53-
102	Allegan	4 N	16 W	21	NE Corner	1831	258-	2.03-
103	Allegan	3 N	16 W	20	N $\frac{1}{4}$ Post	1831	142-	1.13-
104	Allegan	3 N	16 W	32	NE Corner	1831	194-	1.54-
105	Allegan	2 N	16 W	20	NW Corner	1831	196-	1.55-
106	Allegan	2 N	16 W	30	N $\frac{1}{4}$ Post	1831	130-	1.03-
107	Allegan	1 N	17 W	36	NW Corner	1831	227-	1.80-
108	Allegan	1 N	17 W	36	SW Corner	1831	166-	1.32-
109	Van Buren	1 S	17 W	15	NW Corner	1830	348-	2.74-
110	Van Buren	1 S	17 W	28	N $\frac{1}{4}$ Post	1830	177-	1.40-
111	Berrien	3 S	18 W	21	SE Corner	1830	390-	3.07-
112	Berrien	3S	18 W	31	SE Corner	1830	25-	0.20-
113	Berrien	4 S	18 W	6	SE Corner	1830	354-	2.79-
114	Berrien	5 S	19 W	3	NE Corner	1829	258-	2.01-
115	Berrien	5 S	19 W	3	SW Corner	1829	142-	1.11-
116	Berrien	5 S	19 W	16	N $\frac{1}{4}$ Post	1829	256-	2.00-
117	Berrien	7 S	20 W	9	S $\frac{1}{4}$ Post	1829	185-	1.45-
118	Berrien	7 S	21 W	25	S $\frac{1}{4}$ Post	1829	372-	2.91-
119	La Porte, Ind.	38 N	3 W	12	SW Corner	1937	45-	2.25-
120	Porter	38 N	5 W	35	NW $\frac{1}{4}$ SE $\frac{1}{4}$	1927	88-	3.03-
121	Porter	38 N	5 W	35	Near N-S $\frac{1}{4}$ Line	1927	68-	2.34-

No.	County	Tier	Range	Sec.	Description	Date Orig. Survey	Gain(—) or loss (—) in feet to 1956-57	Change Per Year
122	Porter	38 N	5 W	35	Near SW Corner	1927	117-	4.03-
123	Porter	37 N	5 W	3	NE $\frac{1}{4}$ NE $\frac{1}{4}$	1927	86-	2.97-
124	Porter	37 N	5 W	3	NW $\frac{1}{4}$ NE $\frac{1}{4}$	1927	62-	2.14-
125	Porter	37 N	5 W	3	SW $\frac{1}{4}$ NW $\frac{1}{4}$	1927	60-	2.07-
126	Porter	37 N	5 W	4	SE$\frac{1}{4}$ NE $\frac{1}{4}$	1927	72-	2.48
127	Porter	37 N	5 W	4	NW $\frac{1}{4}$ SE $\frac{1}{4}$	1927	112-	3.86-

<u>Summary</u>: Number of Stations: 134.

Number showing net accretion: 6.

Average gain per year at the 6: 1.59 feet.

Number showing no change: 4.

Number showing net erosion loss: 124.

Average loss per year at the 124: 1.47 feet.

Relation of Shore Changes to Lake Levels

It is apparent that the rate of shore change, particularly erosion, has varied greatly. The factors chiefly responsible for such variation in rate of erosion are protective structures built by man, storms of unusual severity, and fluctuations in mean lake level.

Protective structures have been placed along the lake shore at many points by individuals and by municipalities, highway departments, railroads and other large organizations. The scale of such structures ranges from inexpensive groins or seawalls of boulders placed at one or two points, to massive piers and walls of driven steel piling, cement, and heavy riprap so

placed as to protect shore segments several hundred yards in length. Where such protective structures have been properly designed, sturdily built, and of a scale sufficient to protect the entire area of critical erosion, they have generally retarded or checked recession of the shore. Where they have failed in their purpose, the failure has commonly been due to faulty design, weak construction, and inadequate coverage of the shore segment undergoing erosion. A single individual can seldom cope effectively with erosion of his shore, partly because the cost of proper structures is generally beyond his means, but also because shore erosion will continue on both sides of his property, which then becomes subject to attack on 3 sides (see Figure 8). Because the problem of such shore protection has been long and successfully investigated by the U. S. Army, Corps of Engineers, and by private engineering organizations, it will not be discussed further in this report.

Unusually severe storms occur at irregular intervals and have often caused accelerated erosion of the shore. Among them are the storms of October 22 and 29, 1929; September 28, 1945; May 28–29, 1947; January 1 and March 26–28, 1948. The unusual vigor of wave attack during such storms is due partly to greatly increased wind velocity and hence wave energy and height of waves; and partly to the rise in water level associated with strong onshore winds. Such high water may exceed mean level for the period by as much as two feet. Data on actual losses to the shoreline during such storms are meager. Recession of from one to several feet during a single storm have been reported. Because quantitative data over a considerable period of time are lacking, no evaluation of the total effects of unusual storms can be made here.

It has long been known that fluctuations occur in the mean monthly and annual levels of Lake Michigan. Fluctuations of even shorter periods, often

less than one day, are also known and are attributed to changes in wind direction and barometric pressure.* The monthly fluctuations follow somewhat

* Powers, W. E., Effects of Barometric Pressure and Winds on the Level of Lake Michigan: Trans., Illinois State Acad. of Science, vol. 27, 1934, pp. 113-114.

irregularly an annual cycle involving high water in early summer and low water in winter. The annual fluctuations are related partly to rainfall variations but even more to variations in rate of evaporation. Mean annual lake levels rise and fall irregularly with peaks occurring every 10 to 12 years. Since 1864, peaks in the lake level curve have occurred in 1870, 1876, 1886, possibly 1893, 1899, 1905-8, 1918, 1929, 1943-1952. Levels were very low in 1925-26, and 1932-37. They were generally high for the decade 1943-52.

It is apparent that most shore erosion and recession occur during periods of high water. Dated photographs of bluffs, taken in past years, commonly show grassed and stable slopes during low water periods, but fresh cuts and evidences of rapid erosion during high water. Newspaper accounts of wave damage prove the same relationship. However, there are few actual measurements recorded from year to year which permit the relationship of erosion rate to lake level to be put on a quantitative basis. By statistical analysis, involving known fluctuations in lake level and varying rates of erosion along the shore, the Beach Erosion Board estimated that bluff recession in Milwaukee County averages 1.0 foot per year for a maximum lake level of 579 feet; 2.1 feet per year for 581 feet; and 3.2 feet per year for 583 feet.** Your

** Beach Erosion Board, U. S. Army Corps of Engineers, Beach Erosion Study, Lake Michigan Shore Line of Milwaukee County, Wisconsin: U. S. House of Representatives, 79th Congress, 2nd Session, Document No. 526, 1946.

author believes that these figures are conservative and that annual erosion at the 583-foot level would probably be far more than 3.2 times that at the 579-foot level. The work of J. R. Ball near Kenosha, quoted previously under "Former Studies of Shoreline "Changes," showed an average annual recession of 12.33 feet per year from 1918 to 1921, when lake level averaged about 580.6 feet; and 0.73 feet per year from 1921 to 1929, when lake level averaged about 579.3 feet. It is apparent that yearly measurements on erosion over a period of years are needed, before a quantitative relationship can be established between lake levels and erosion rates.

A human factor also enters into this problem. Long periods of low lake levels, as that between 1929 and 1943, are times of broad beaches and feeble wave attack on the shore. Groins and other protective structures are allowed to lapse into disrepair. Then when another high water period arrives, the decayed shore structures may be quickly destroyed by wave action, and the shore is left open to attack. Such was the situation in 1943, when the unexpected return to a high water level promptly caused serious damage to the shore and shore properties, which owners often did not have the means to combat immediately.

APPLICABILITY OF SHORELINE STUDIES ON LAKE MICHIGAN TO OTHER LARGE INLAND LAKES

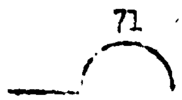
Comparable Large Lakes Elsewhere

Lakes comparable in size to Lake Michigan include Superior, Huron, Erie, and Ontario in the United States; Winnipeg, Athabaska, Great Slave, and Great Bear in Canada; Caspian Sea, Aral Sea, Ladoga, Balkhash, and Baikal in Eurasia; and Victoria, Rudolf, Albert, Nyasa, and Tanganyika in Africa. Although

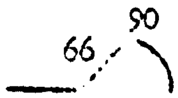
differing greatly from Lake Michigan in outline, geological structure and history, most of these lakes possess many similarities to Lake Michigan. A few differ notably in one particular: they lie deep below surrounding mountains or elevated plateaus. Specifically, Lake Baikal lies amidst mountains, while all of the African lakes except Victoria are in valleys sunk deeply below a plateau surface. On the contrary, the others are all in plains or lowlands and their shorelines possess many similarities to that of Lake Michigan.

Processes similar to those on Lake Michigan are now modifying the coast zones of these other large lakes, and have done so in the past. Similar basic shore zone features have been developed, including bluffs, cliffs, dunes, bars, and nips. With appropriate modifications where necessary, the letter code used for describing the shore zone elements of Lake Michigan can be applied to all other large lakes. Most of the larger shore zone features identified on Lake Michigan can be recognized on good aerial photos of large scale; this statement applies particularly to bluffs, cliffs, dunes, low plains, and other major features. Widths of beaches can be measured from the photos; areas of active erosion can be identified by narrow beach zones and lack of vegetation on fresh bluffs; the nature of beach materials can usually be deduced from the character of the landface and backland areas and the inferred nature of shore processes. Associations of shore zone features, observed in the Lake Michigan area, can be extended to other large lake basins. Therefore the types of shore zone features on Lake Michigan, the methods developed for mapping them in code, and their observed combinations and associations, can be applied to the study of any other large lake. By such study, shore zone areas can be identified which are best suited for man's operations, of whatever character they may be.

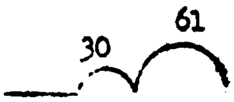
APPENDIX I. Explanation of Graphic Symbols used on the 26 Section Maps of the Lake Michigan Shore.



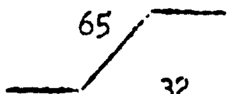
Dune 71 feet high. Shore at left.



Dune 90 feet high, with bluff 66 feet high.



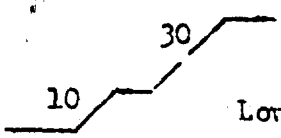
Dune 30 feet high, in front of dune 61 feet high.



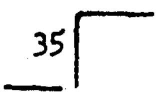
Bluff 65 feet high.

Dune 32 feet high, on upland with bluff 50 feet high.

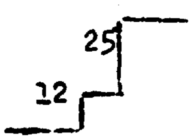
Dune at base of bluff 36 feet high.



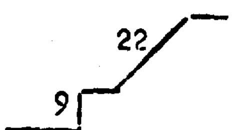
Lower and higher bluffs, 10 and 30 feet high.



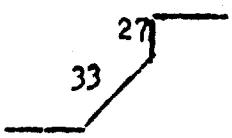
Rock cliff 35 feet high.



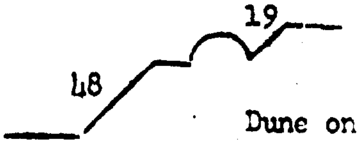
Lower and higher rock cliffs, 12 and 25 feet high.



Rock cliff 9 feet high, below; Bluff 22 feet high, above.



Bluff 33 feet high, below; cliff 27 feet high, above.



Dune on upland; bluffs below and above.

APPENDIX II. Code (Letter and Numeral) Used in Field Mapping, in Table II, in Descriptions of Figures, and on the 26 Section Maps Showing Characteristics of the Shore Zone.

A. Upland with bluff.
Ah — high bluff, more than 20 feet high.
Al — low bluff, less than 20 feet high.
Materials of bluff and backland:
1. Glacial till
2. Glacial sand and gravel
3. Dune sand
4. Lacustrine sand and gravel
5. Lacustrine silt or clay
Examples: Ah-1, high upland of till, with bluff.
Al-1/4, low upland of till over lacustrine sand and gravel, with bluff.

B. Low plain, generally without nip.
Materials of plain:
1 to 5. Same as above
6. Stream alluvium, mainly gravel, sand mud and silt
7. Swamp
8. Bedrock
If rock ledge or reef occurs in beach zone, r is added.
Example: B-2-r, low plain of glacial sand and gravel, with reef on beach.

C. Foredunes, mostly less than 20 feet high.
Cb, if low bluff or nip is present.
C, if no bluff or nip is present.

D. Old dunes, generally wooded and mostly more than 20 feet high.
Dh — high dunes, more than 40 feet high.
Dl — low dunes, less than 40 feet high.
If bluff is present b is added.
Example: Dlb, low dunes with bluff.

M E. Sand bar or spit.
If dunes are on top, d is added.
Example: Ed, spit or bar with dunes.

F. Bedrock upland with cliff.
Fh — high cliff, more than 20 feet high.
Fl — low cliff, less than 20 feet high.

M. Reed marsh in offshore or foreshore. Generally no beach is present. This type occurs with other basic types of coastal features.
Example: B-4-M: Low plain of lacustrine sand and gravel, with reed marsh offshore.

R. Artificial fill. This generally occurs with some other basic types of coastal features.
Example: Al-2-R, upland of glacial sand and gravel with bluff less than 20 feet high, with artificial fill along "shore."

Distribution List
Technical and Final Reports
NR 387-015
Contract No. Nonr-1228(07)

Chief of Naval Research (2)
Attention: Geography Branch
Office of Naval Research
Washington 25, D.C.

Armed Services Technical Information Agency (5)
Documents Service Center
Knott Building
Dayton 2, Ohio

Director, Naval Research Laboratory (6)
Attention: Technical Information Officer
Washington 25, D.C.

Commanding Officer (1)
Office of Naval Research Branch Office
346 Broadway
New York 13, New York

Commanding Officer (1)
Office of Naval Research Branch Office
1030 East Green Street
Pasadena 1, California

Commanding Officer (1)
Office of Naval Research Branch Office
The John Crerar Library Building
86 East Randolph Street
Chicago 1, Illinois

Commanding Officer (2)
Office of Naval Research
Navy #100
Fleet Post Office
New York, New York

Chief of Naval Operations (Op-922F4C)
Department of the Navy
Washington 25, D.C. (1)

The Hydrographer (1)
U.S. Navy Hydrographic Office
Suitland, Maryland

Officer-in-Charge (1)
Attention: Mr. Page Truesdell
U.S. Naval Photographic Interpretation Center
U.S. Naval Receiving Station
Anacostia, Washington, D.C.

Chief, Bureau of Yards and Docks (P-300) (1)
Department of the Navy
Washington 25, D.C.

Photo Intelligence Section (1)
Reconnaissance Branch
Directorate of Intelligence, U.S. Air Force
Room 4C1040, Pentagon
Washington 25, D.C.

Headquarters, Quartermaster Research and Development Command (1)
Quartermaster Research and Development Center
U.S. Army
Natick, Massachusetts
Attention: Environmental Protection Division

Engineer Intelligence Division (1)
Office of the Chief of Engineers
Gravelly Point, Building T-7
Washington 25, D.C.

Resident Member (1)
Corps of Engineers, U.S. Army
Beach Erosion Board
5201 Little Falls Road, N.W.
Washington 16, D.C.

Distribution List
Technical and Final Reports
NR 387-015
Contract No. Nonr-1228(07)

Director of Intelligence (1)
General Staff, U.S. Army
Pentagon Building
Washington 25, D.C.

Director of Central Intelligence Agency (1)
Attention: Map Division
2430 E Street, N.W.
Washington 25, D.C.

Commandant (1)
U.S. Coast Guard
Headquarters
Washington 25, D.C.

Director (1)
U.S. Coast and Geodetic Survey
Department of Commerce
Washington 25, D.C.

Dr. Frank C. Whitmore, Jr. (1)
Military Geology Branch
U.S. Geological Survey
Department of the Interior
Room 4227, GSA Building
Washington 25, D.C.

Dr. Edwin H. Hammond (1)
Department of Geography
University of Wisconsin
Madison 6, Wisconsin

Dr. H.T.U. Smith (1)
Department of Geology
University of Massachusetts
Amherst, Massachusetts

Dr. William C. Putnam (1)
Department of Geology
University of California
Los Angeles, California

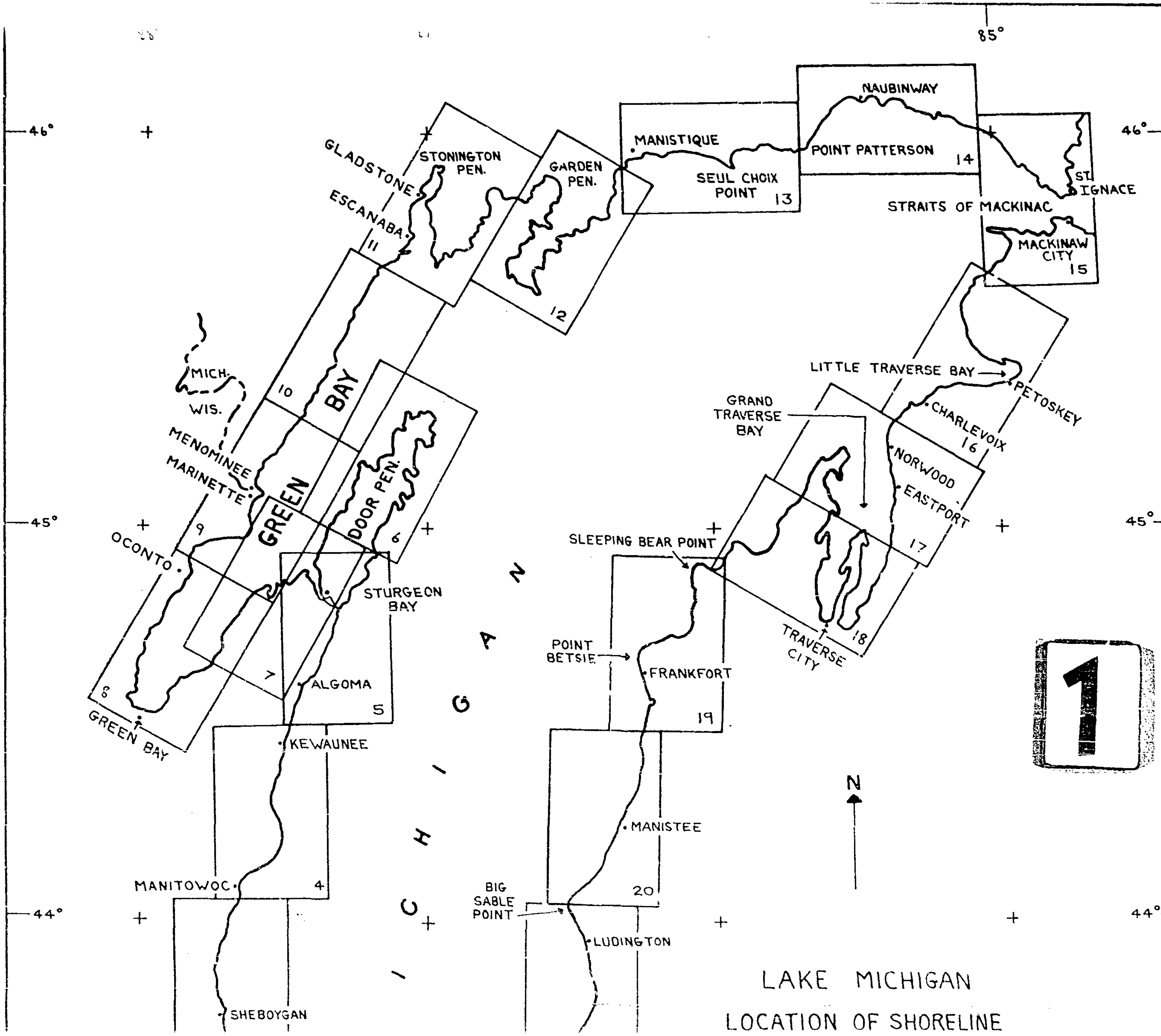
Dr. Richard J. Russell (1)
Dean of the Graduate School
Louisiana State University
Baton Rouge 3, Louisiana

Dr. Carl O. Sauer (1)
Department of Geography
University of California
Berkeley 4, California

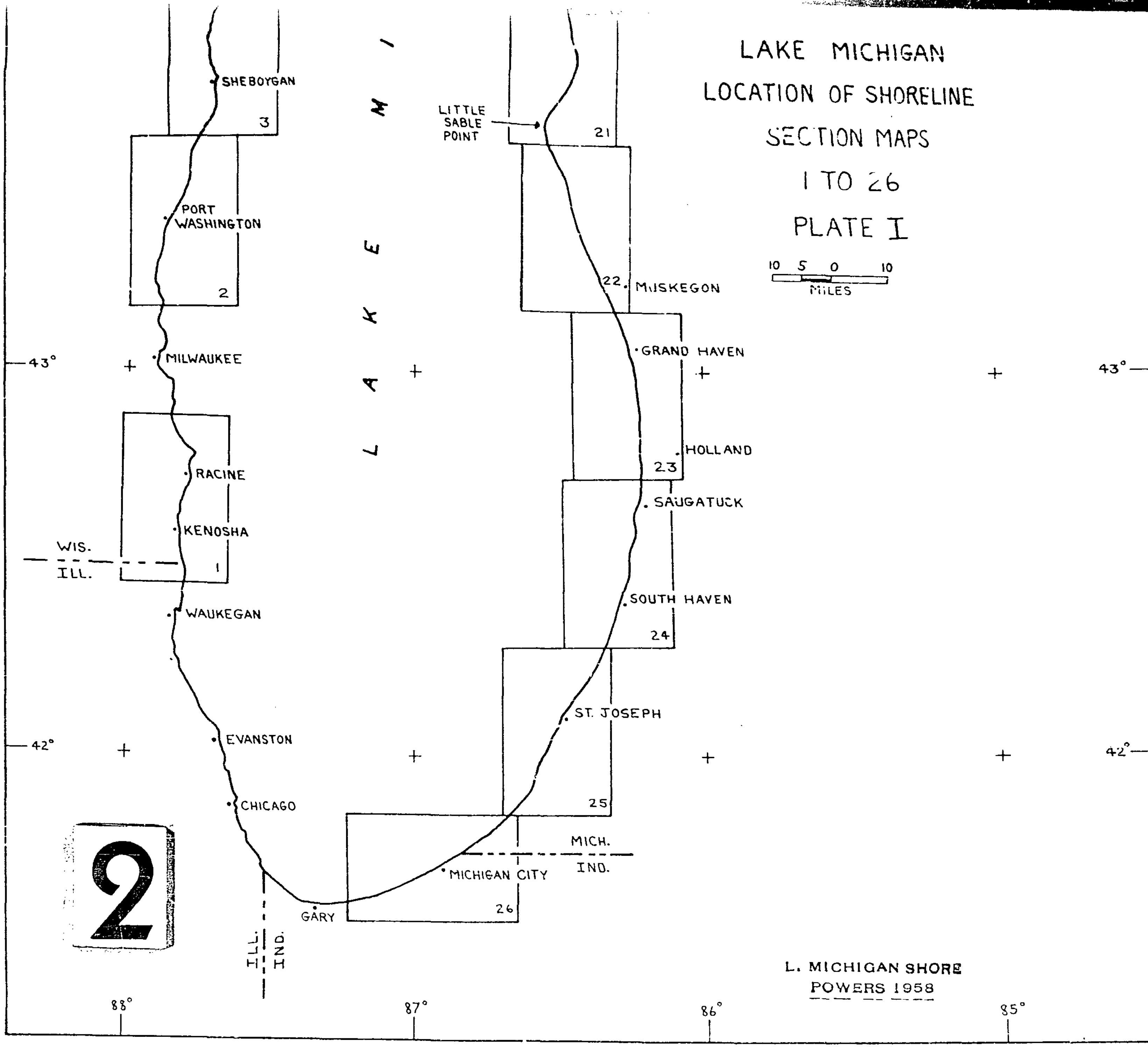
Dr. John M. Zeigler (1)
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

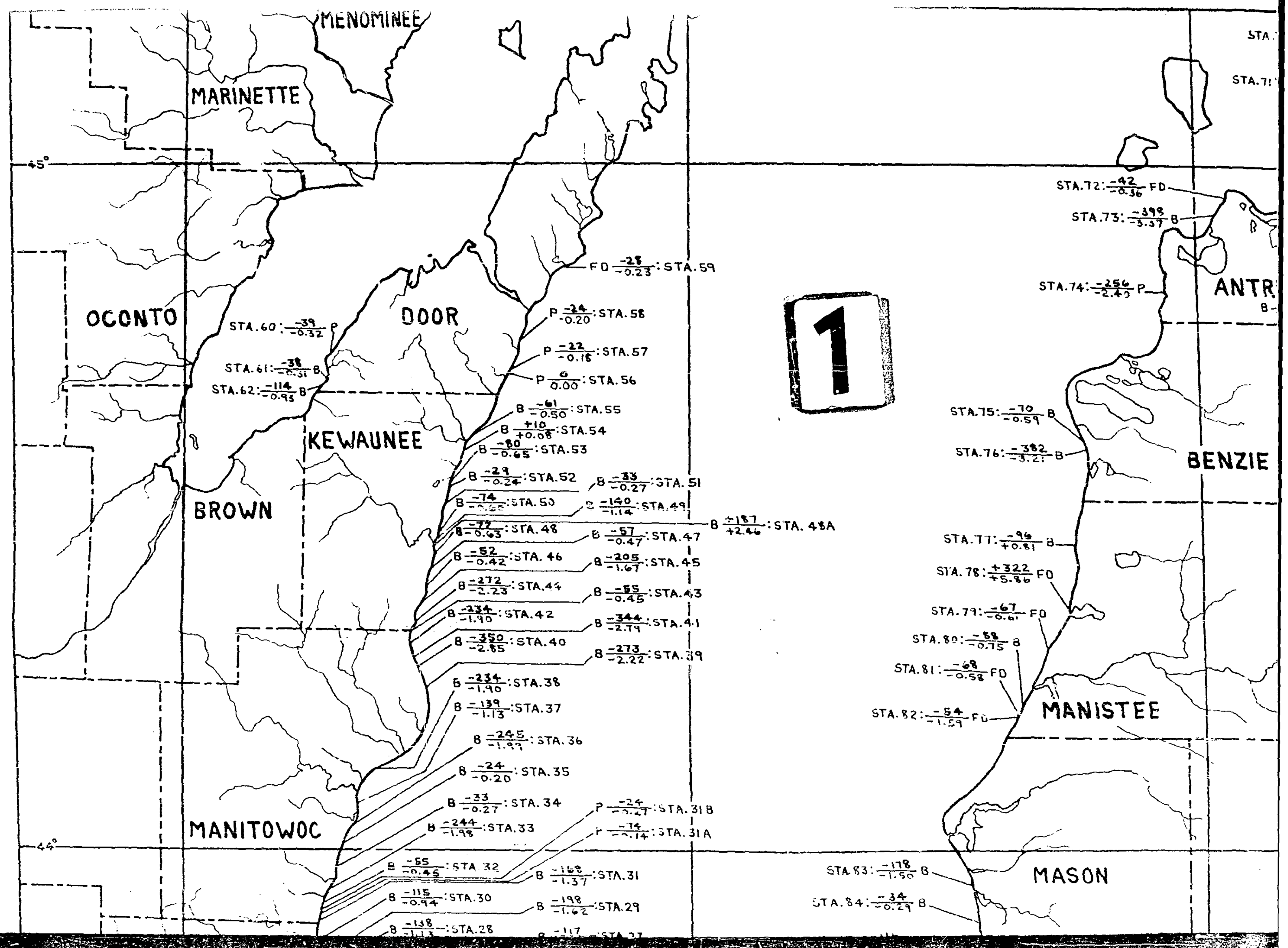
Mr. Charles B. Hitchcock (1)
American Geographical Society
Broadway at 156th Street
New York 32, New York

Dr. Arthur N. Strahler (1)
Department of Geology
Columbia University
New York 27, New York

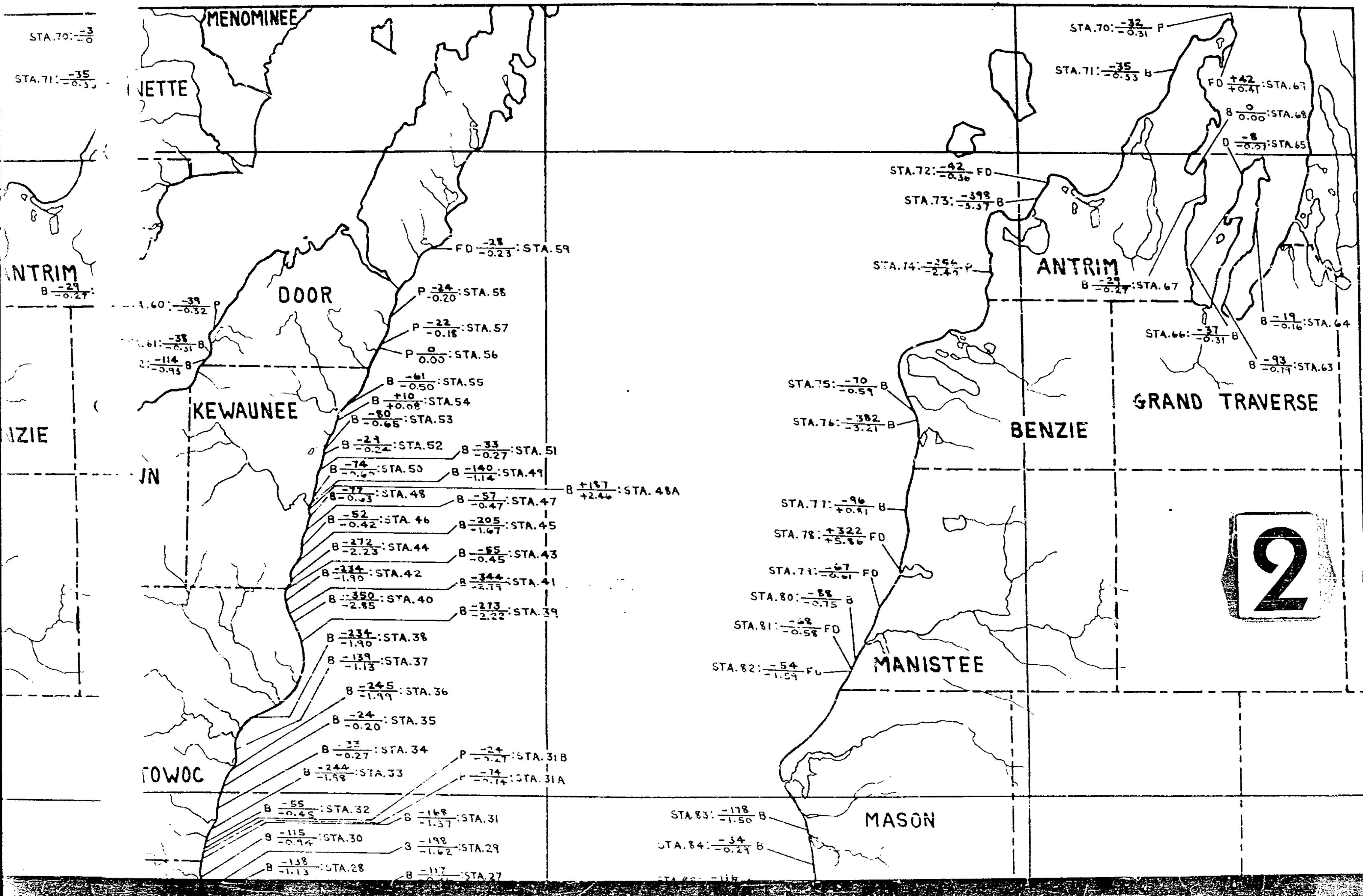


LAKE MICHIGAN
LOCATION OF SHORELINE
1
N
85°
46°
45°
44°
NAUBINWAY
POINT PATTERSON
MANISTIQUE
SEUL CHOIX POINT
ST. IGNACE
STRAITS OF MACKINAC
MACKINAW CITY
GLADSTONE
ESCANABA
STONINGTON PEN.
GARDEN PEN.
LITTLE TRAVERSE BAY
PETOSKEY
CHARLEVOIX
NORWOOD
EASTPORT
GRAND TRAVERSE BAY
TRAVERSE CITY
SLEEPING BEAR POINT
POINT BETSIE
FRANKFORT
MANISTEE
BIG SABLE POINT
LUDINGTON
MICH.
WIS.
MENOMINEE
MARINETTE
GREEN BAY
DOOR PEN.
OCONTO
STURGEON BAY
ALGOMA
KEWAUNEE
MANITOWOC
SHEBOYGAN
GREEN BAY
MICHIGAN
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

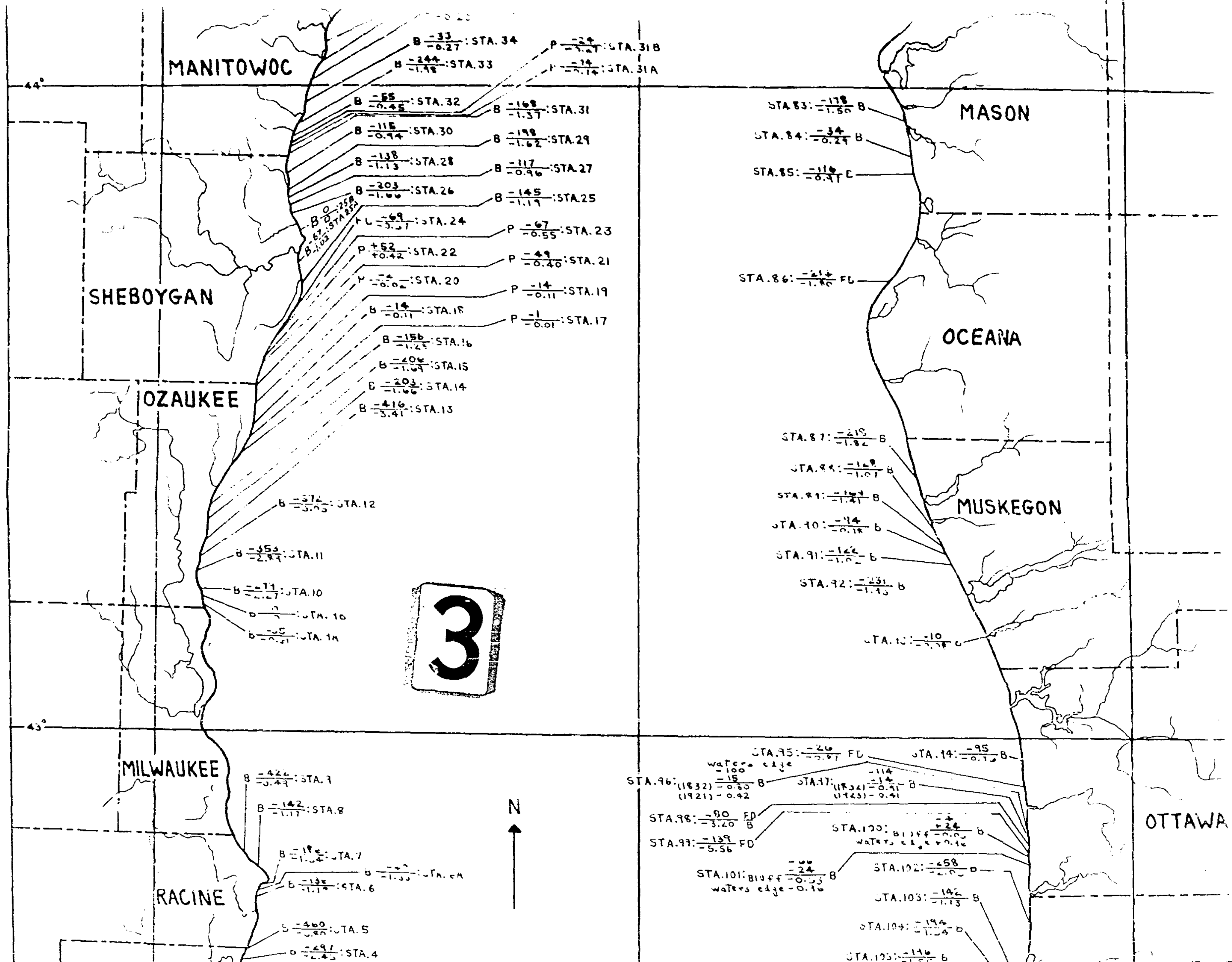

LAKE MICHIGAN
LOCATION OF SHORELINE
SECTION MAPS
1 TO 26
PLATE I
10 5 0 10
MILES
LAKE MI
SHEBOYGAN
3
PORT WASHINGTON
2
MILWAUKEE
43°
RACINE
KENOSHA
WIS.
ILL.
1
WAUKEGAN
EVANSTON
42°
CHICAGO
GARY
ILL.
IND.
LITTLE SABLE POINT
21
22
MUSKEGON
GRAND HAVEN
HOLLAND
23
SAUGATUCK
SOUTH HAVEN
24
ST. JOSEPH
25
MICH.
IND.
MICHIGAN CITY
26
88°
87°
86°
85°
2
L. MICHIGAN SHORE
POWERS 1958



MENOMINEE
MARINETTE
OCONTO
DOOR
KEWAUNEE
BROWN
MANITOWOC
BENZIE
MANISTEE
MASON
ANTR
45°
44°
1
STA.72: -42/-0.36 FD
STA.73: -398/-3.37 B
STA.74: -256/-2.49 P
STA.75: -70/-0.59 B
STA.76: -382/-3.21 B
STA.77: -96/+0.81 B
STA.78: +322/+5.86 FD
STA.79: -67/-0.61 FD
STA.80: -88/-0.75 B
STA.81: -68/-0.58 FD
STA.82: -54/-1.59 FD
STA.83: -178/-1.50 B
STA.84: -34/-0.29 B
FD -28/-0.23 : STA.59
P -24/-0.20 : STA.58
P -22/-0.18 : STA.57
P 0/0.00 : STA.56
B -61/-0.50 : STA.55
B +10/+0.08 : STA.54
B -80/-0.65 : STA.53
B -29/-0.24 : STA.52
B -33/-0.27 : STA.51
B -74 : STA.50
B -140/-1.14 : STA.49
B -72/-0.63 : STA.48
B +187/+2.46 : STA. 48A
B -57/-0.47 : STA.47
B -52/-0.42 : STA. 46
B -205/-1.67 : STA.45
B -272/-2.23 : STA.44
B -55/-0.45 : STA.43
B -234/-1.90 : STA.42
B -344/-2.79 : STA.41
B -350/-2.85 : STA.40
B -273/-2.22 : STA.39
B -234/-1.90 : STA.38
B -139/-1.13 : STA.37
B -245/-1.99 : STA.36
B -24/-0.20 : STA.35
B -33/-0.27 : STA. 34
B -244/-1.98 : STA.33
P -24 : STA.31B
P -14/-0.14 : STA.31A
B -55/-0.45 : STA.32
B -168/-1.37 : STA.31
B -115/-0.94 : STA.30
B -198/-1.62 : STA.29
B -138/-1.13 : STA.28
STA.60: -39/-0.32 P
STA.61: -38/-0.31 B
STA.62: -114/-0.93 B



MENOMINEE
NETTE
DOOR
KEWAUNEE
TOWOC
ANTRIM
BENZIE
GRAND TRAVERSE
MANISTEE
MASON
2
STA.70: $\frac{-32}{-0.31}$ P
STA.71: $\frac{-35}{-0.33}$ B
FD $\frac{+42}{+0.41}$:STA.69
B $\frac{0}{0.00}$:STA.68
D $\frac{-8}{-0.07}$:STA.65
STA.72: $\frac{-42}{-0.36}$ FD
STA.73: $\frac{-398}{-3.37}$ B
STA.74: $\frac{-254}{-2.45}$ P
B $\frac{-29}{-0.27}$:STA.67
B $\frac{-19}{-0.16}$:STA.64
STA.66: $\frac{-37}{-0.31}$ B
B $\frac{-93}{-0.79}$:STA.63
STA.75: $\frac{-70}{-0.59}$ B
STA.76: $\frac{-382}{-3.21}$ B
STA.77: $\frac{-96}{+0.81}$ B
STA.78: $\frac{+322}{+5.86}$ FD
STA.79: $\frac{-67}{-0.61}$ FD
STA.80: $\frac{-88}{-0.75}$ B
STA.81: $\frac{-68}{-0.58}$ FD
STA.82: $\frac{-54}{-1.59}$ FD
STA.83: $\frac{-178}{-1.50}$ B
STA.84: $\frac{-34}{-0.29}$ B
FD $\frac{-28}{-0.23}$:STA.59
P $\frac{-24}{-0.20}$:STA.58
P $\frac{-22}{-0.18}$:STA.57
P $\frac{0}{0.00}$:STA.56
B $\frac{-61}{-0.50}$:STA.55
B $\frac{+10}{+0.08}$:STA.54
B $\frac{-80}{-0.65}$:STA.53
B $\frac{-29}{-0.24}$:STA.52
B $\frac{-33}{-0.27}$:STA.51
B $\frac{-74}{-0.60}$:STA.50
B $\frac{-140}{-1.14}$:STA.49
B $\frac{+187}{+2.46}$:STA.48A
B $\frac{-77}{-0.63}$:STA.48
B $\frac{-57}{-0.47}$:STA.47
B $\frac{-52}{-0.42}$:STA.46
B $\frac{-205}{-1.67}$:STA.45
B $\frac{-272}{-2.23}$:STA.44
B $\frac{-55}{-0.45}$:STA.43
B $\frac{-234}{-1.90}$:STA.42
B $\frac{-344}{-2.79}$:STA.41
B $\frac{-350}{-2.85}$:STA.40
B $\frac{-273}{-2.22}$:STA.39
B $\frac{-234}{-1.90}$:STA.38
B $\frac{-139}{-1.13}$:STA.37
B $\frac{-245}{-1.99}$:STA.36
B $\frac{-24}{-0.20}$:STA.35
B $\frac{-33}{-0.27}$:STA.34
B $\frac{-244}{-1.98}$:STA.33
P $\frac{-24}{-0.21}$:STA.31B
P $\frac{-14}{-0.14}$:STA.31A
B $\frac{-55}{-0.45}$:STA.32
B $\frac{-168}{-1.37}$:STA.31
B $\frac{-115}{-0.94}$:STA.30
B $\frac{-198}{-1.62}$:STA.29
B $\frac{-138}{-1.13}$:STA.28
STA.27
STA.60: $\frac{-39}{-0.32}$ P
STA.61: $\frac{-38}{-0.31}$ B
STA.62: $\frac{-114}{-0.93}$ B



MANITOWOC
SHEBOYGAN
OZAUKEE
MILWAUKEE
RACINE
MASON
OCEANA
MUSKEGON
OTTAWA
44°
43°
N
3
B -33/-0.27 : STA. 34
B -244/-1.98 : STA. 33
P -24 : STA. 31B
STA. 31A
B -65/-0.45 : STA. 32
B -168/-1.37 : STA. 31
B -115/-0.94 : STA. 30
B -198/-1.62 : STA. 29
B -138/-1.13 : STA. 28
B -117/-0.96 : STA. 27
B -203 : STA. 26
B -145/-1.19 : STA. 25
STA. 24
P -67/-0.55 : STA. 23
P +52/+0.42 : STA. 22
P -49/-0.40 : STA. 21
STA. 20
P -14/-0.11 : STA. 19
B -14/-0.11 : STA. 18
P -1/-0.01 : STA. 17
B -156 : STA. 16
STA. 15
B -203 : STA. 14
B -416/-3.41 : STA. 13
STA. 12
STA. 11
STA. 10
B -424 : STA. 9
B -142/-1.17 : STA. 8
STA. 7
STA. 6
STA. 5
STA. 4
STA. 83: -178/-1.50 B
STA. 84: -34/-0.29 B
STA. 85
STA. 86
STA. 87: -215/-1.82 B
STA. 90: -14 B
STA. 92: -231 B
STA. 94: -95 B
STA. 95: -26 FD
waters edge
-100
STA. 96: (1832) -15/-0.80 B
(1921) - 0.42
STA. 97
-114
-14
STA. 98: -80/-3.20 FD B
STA. 99: -139/-5.56 FD
STA. 100: Bluff
waters edge
-24
STA. 101: Bluff
waters edge -0.16
STA. 102: -458
STA. 103: -142/-1.13 B
STA. 104
STA. 105

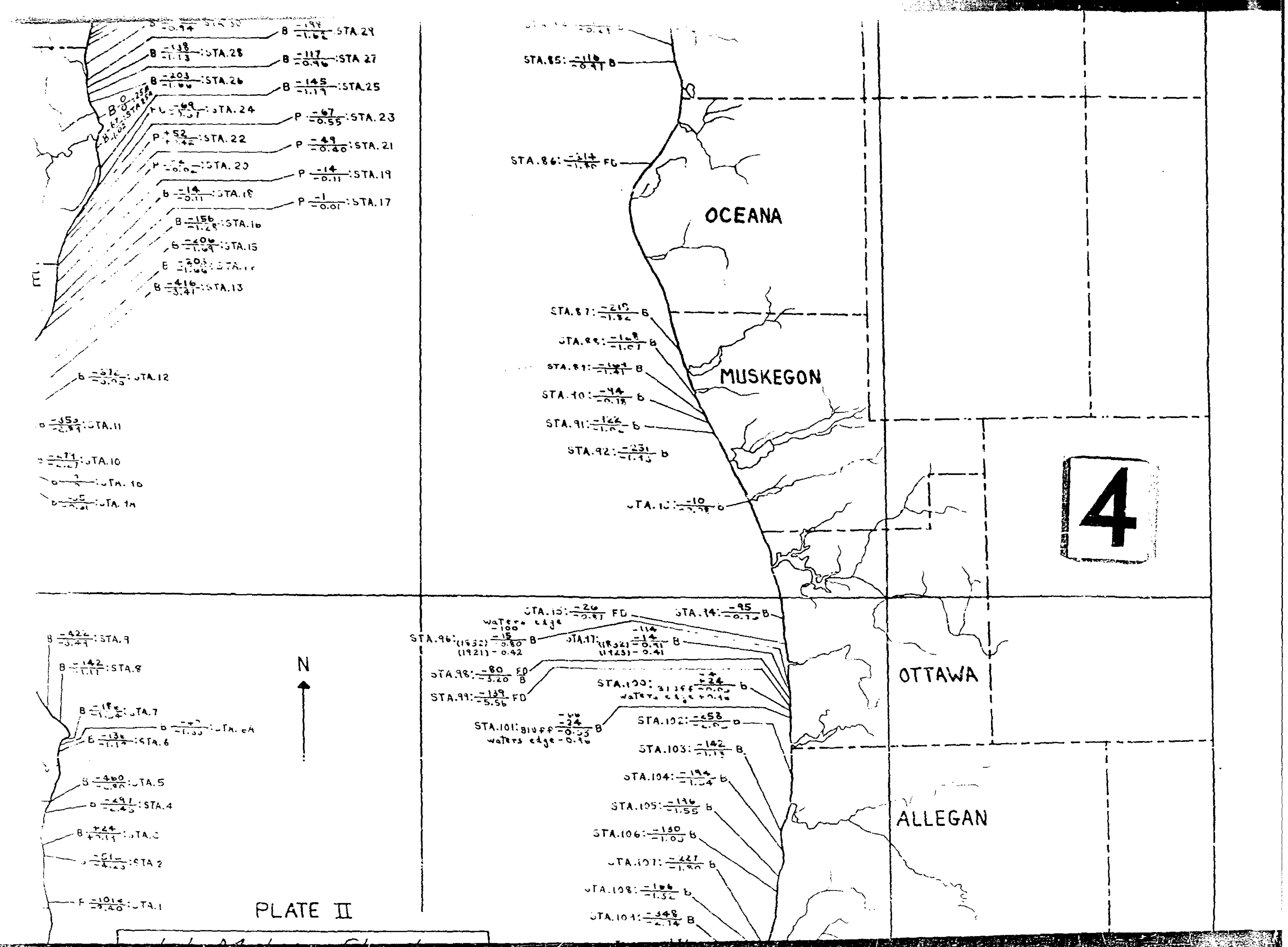
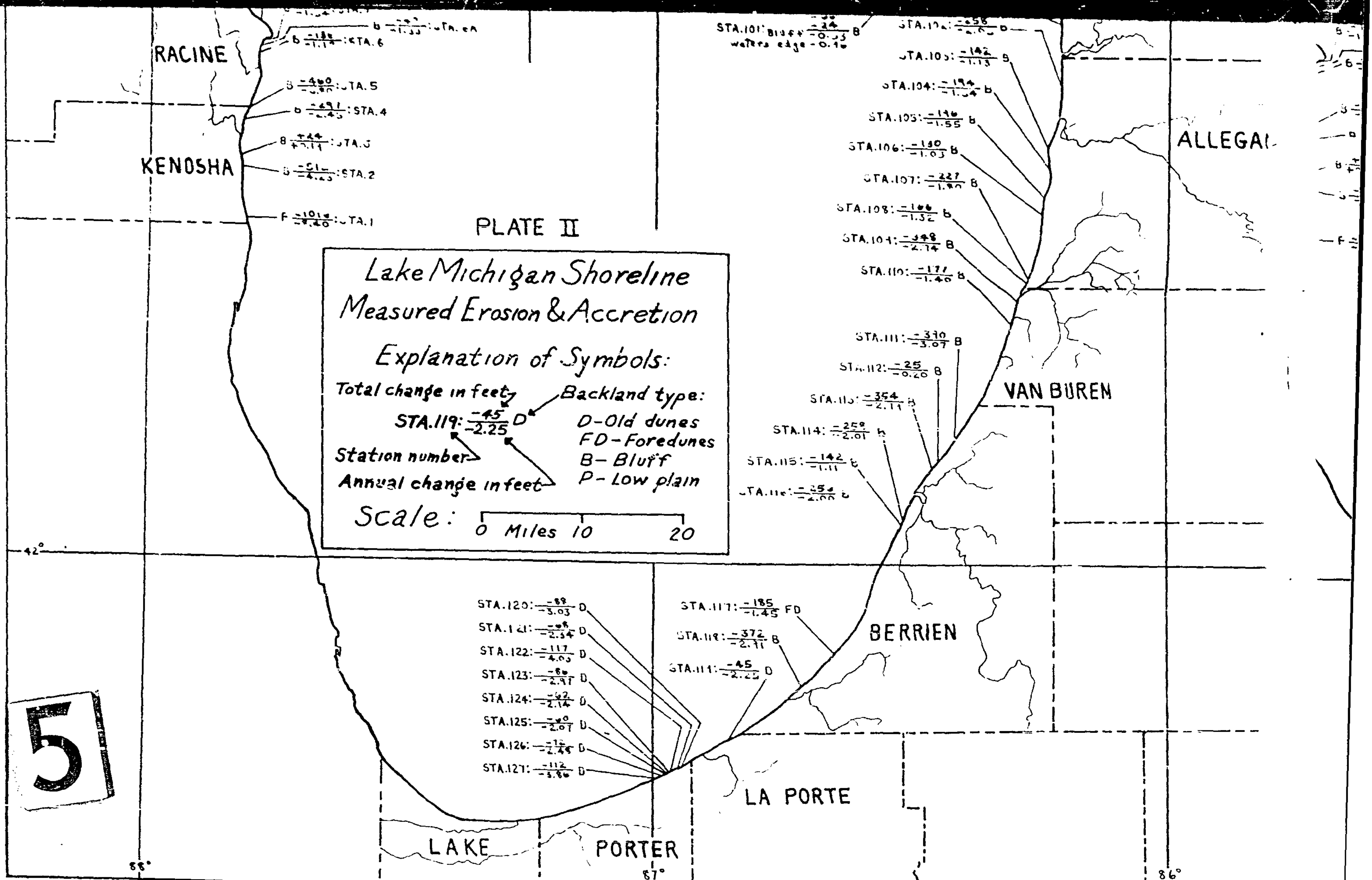
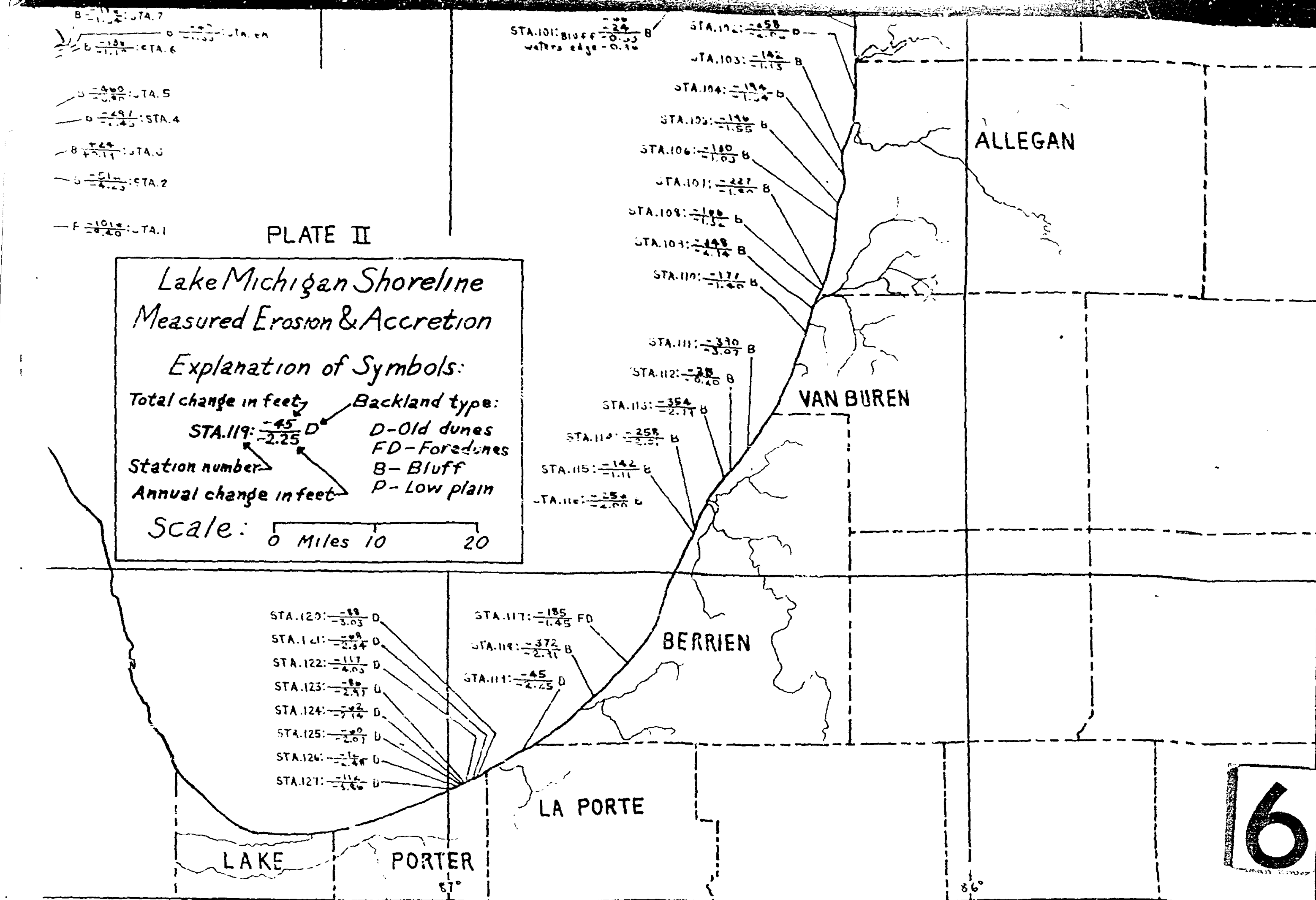

OCEANA
MUSKEGON
OTTAWA
ALLEGAN
4
N
STA. 85
STA. 86
STA. 87
STA. 91
STA. 92
STA. 96
STA. 98
STA. 99
STA. 101
STA. 102
STA. 103
STA. 104
STA. 105
STA. 106
STA. 108
STA. 29
STA. 28
STA 27
STA. 26
STA. 25
STA. 24
STA. 23
STA. 22
STA. 21
STA. 20
STA. 19
STA. 17
STA. 16
STA. 15
STA. 13
STA. 12
STA. 11
STA. 10
STA. 9
STA. 8
STA. 7
STA. 6
STA. 5
STA. 4
STA. 2
waters edge

PLATE II



LAKE MICHIGAN SHORELINE - POWL

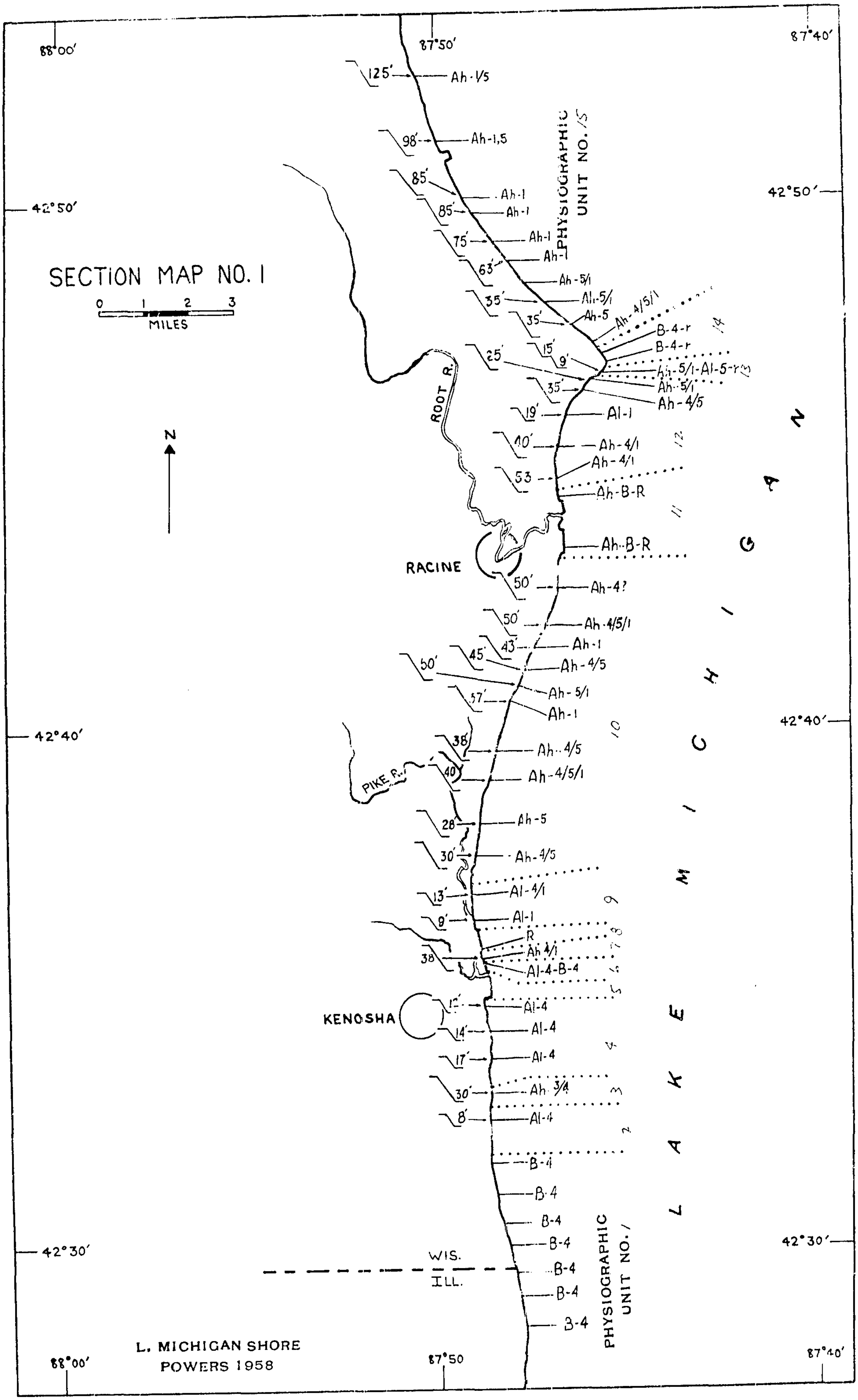
PLATE II



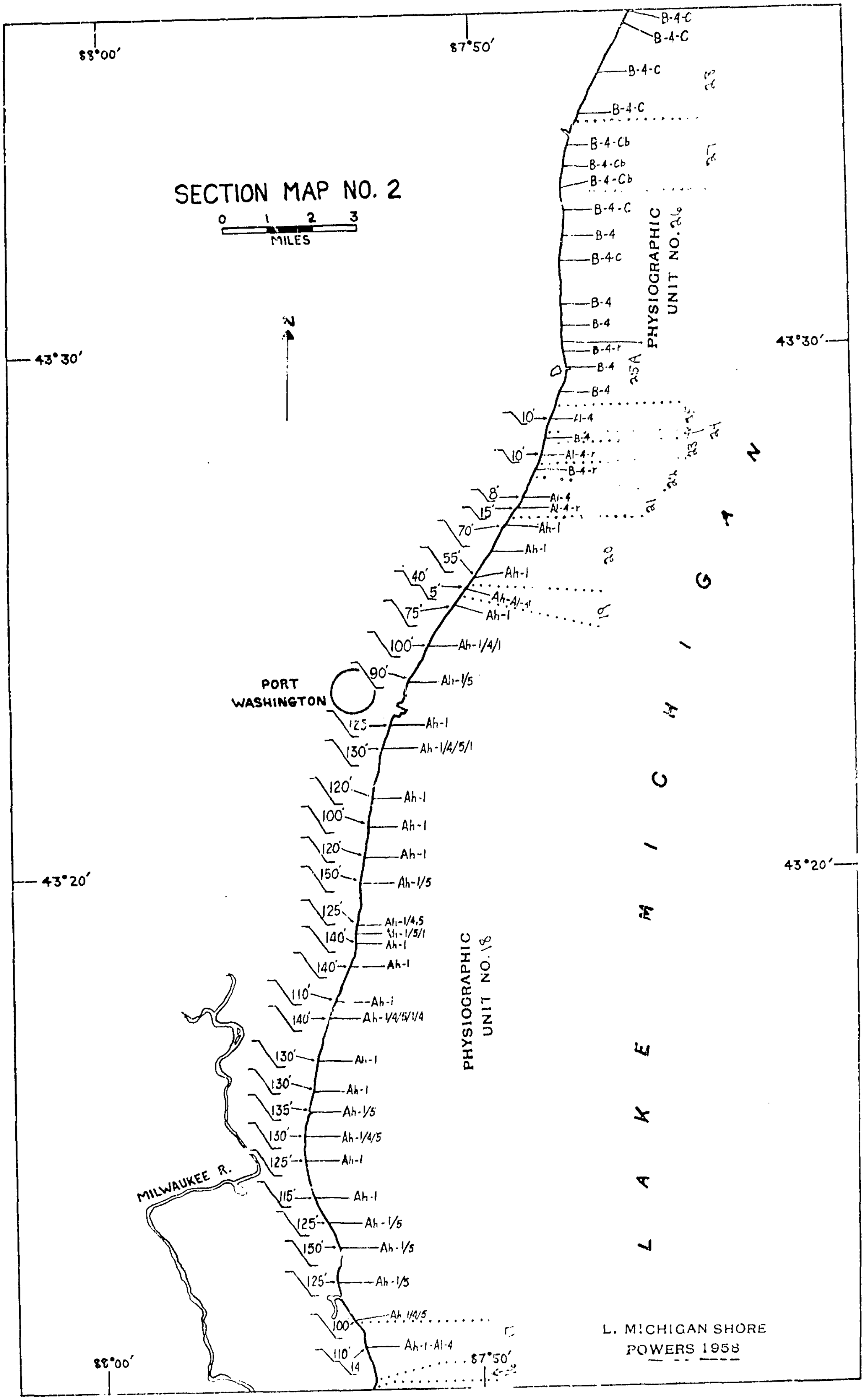
6

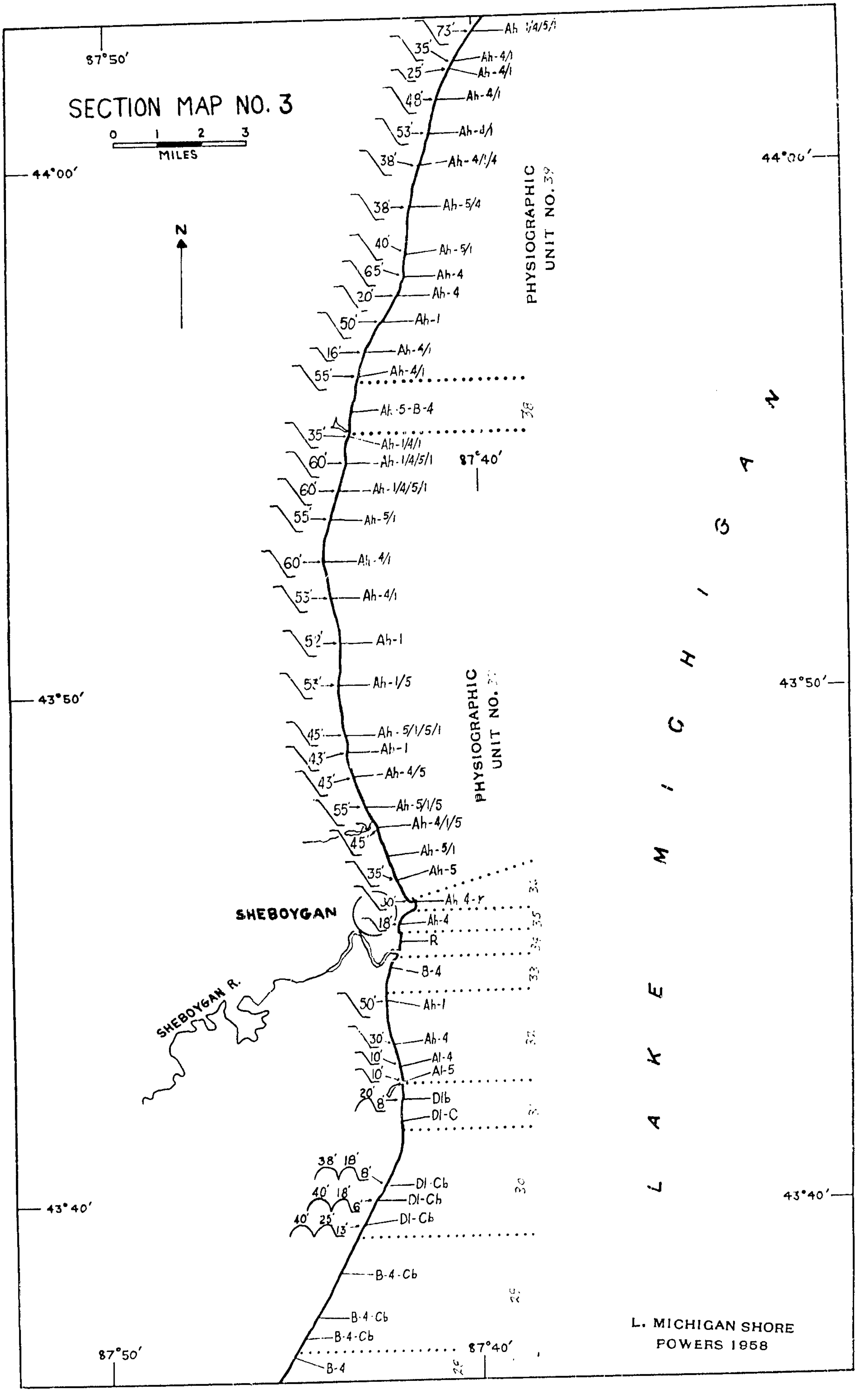
LAKE MICHIGAN SHORELINE - POWERS - 1958

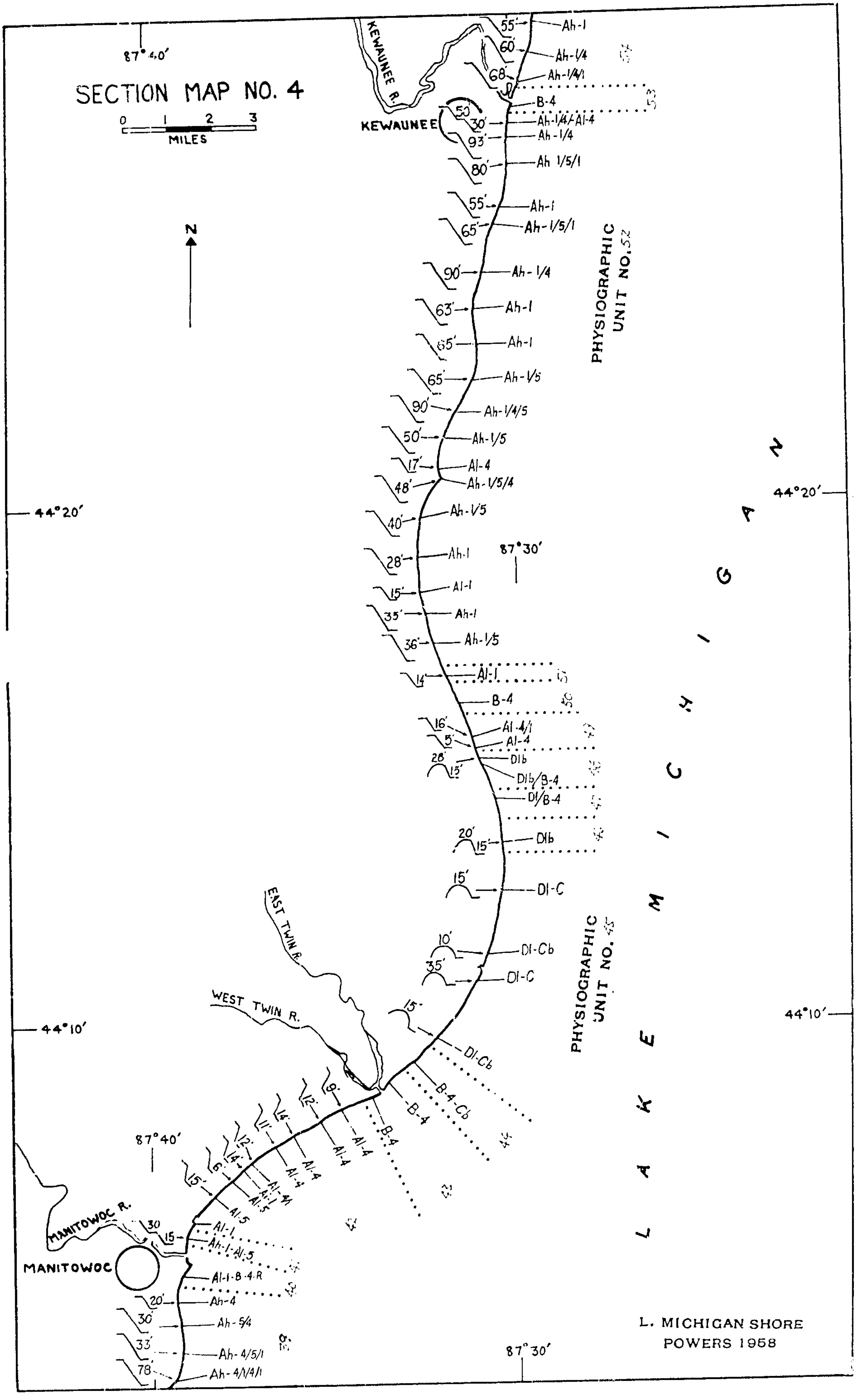
PLATE II



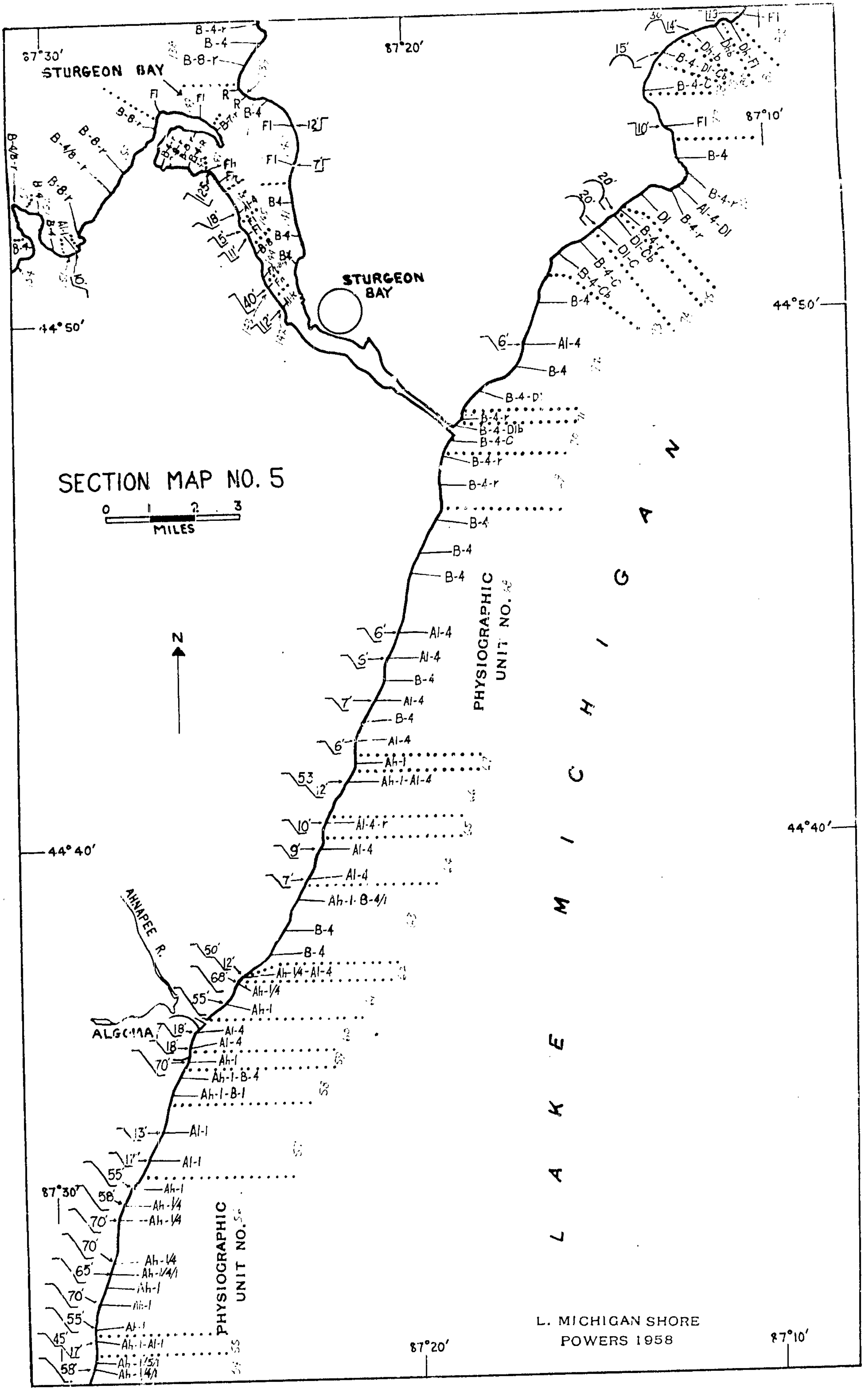
SECTION MAP NO. I
0 1 2 3
MILES
N
RACINE
KENOSHA
ROOT R.
PIKE R.
WIS.
ILL.
PHYSIOGRAPHIC UNIT NO. 15
PHYSIOGRAPHIC UNIT NO. 1
LAKE MICHIGAN
L. MICHIGAN SHORE
POWERS 1958

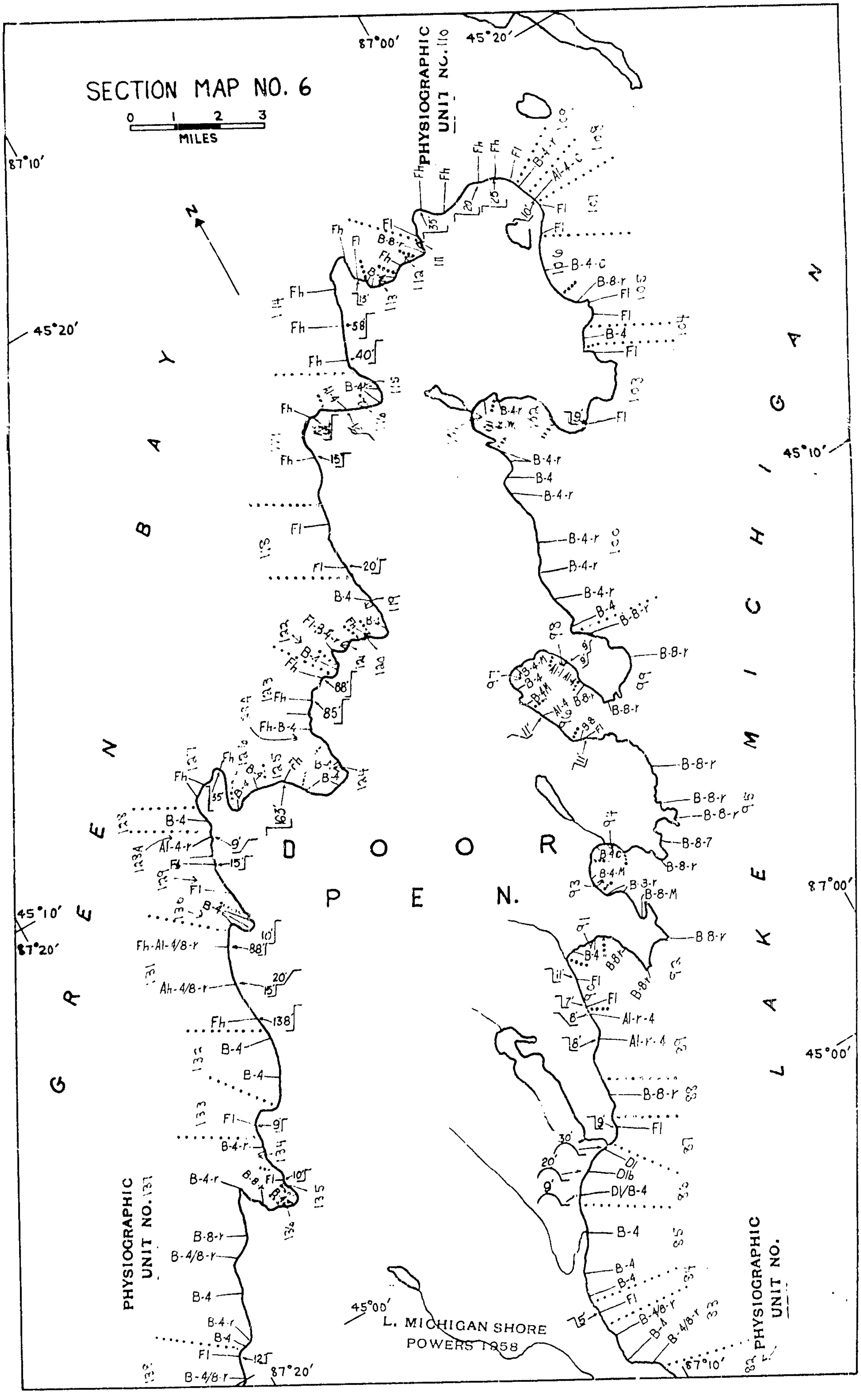

SECTION MAP NO. 2
0 1 2 3
MILES
N
88°00'
87°50'
43°30'
43°20'
PORT WASHINGTON
MILWAUKEE R.
PHYSIOGRAPHIC UNIT NO. 26
PHYSIOGRAPHIC UNIT NO. 18
25A
LAKE MICHIGAN
B-4-C
B-4-Cb
B-4
B-4-r
Al-4
Al-4-r
Ah-1
Ah-1/4/1
Ah-1/5
Ah-1/4/5/1
Ah-1/4,5
Ah-1/4'5/1/4
Ah-1/4/5
Ah-1-Al-4
L. MICHIGAN SHORE
POWERS 1958

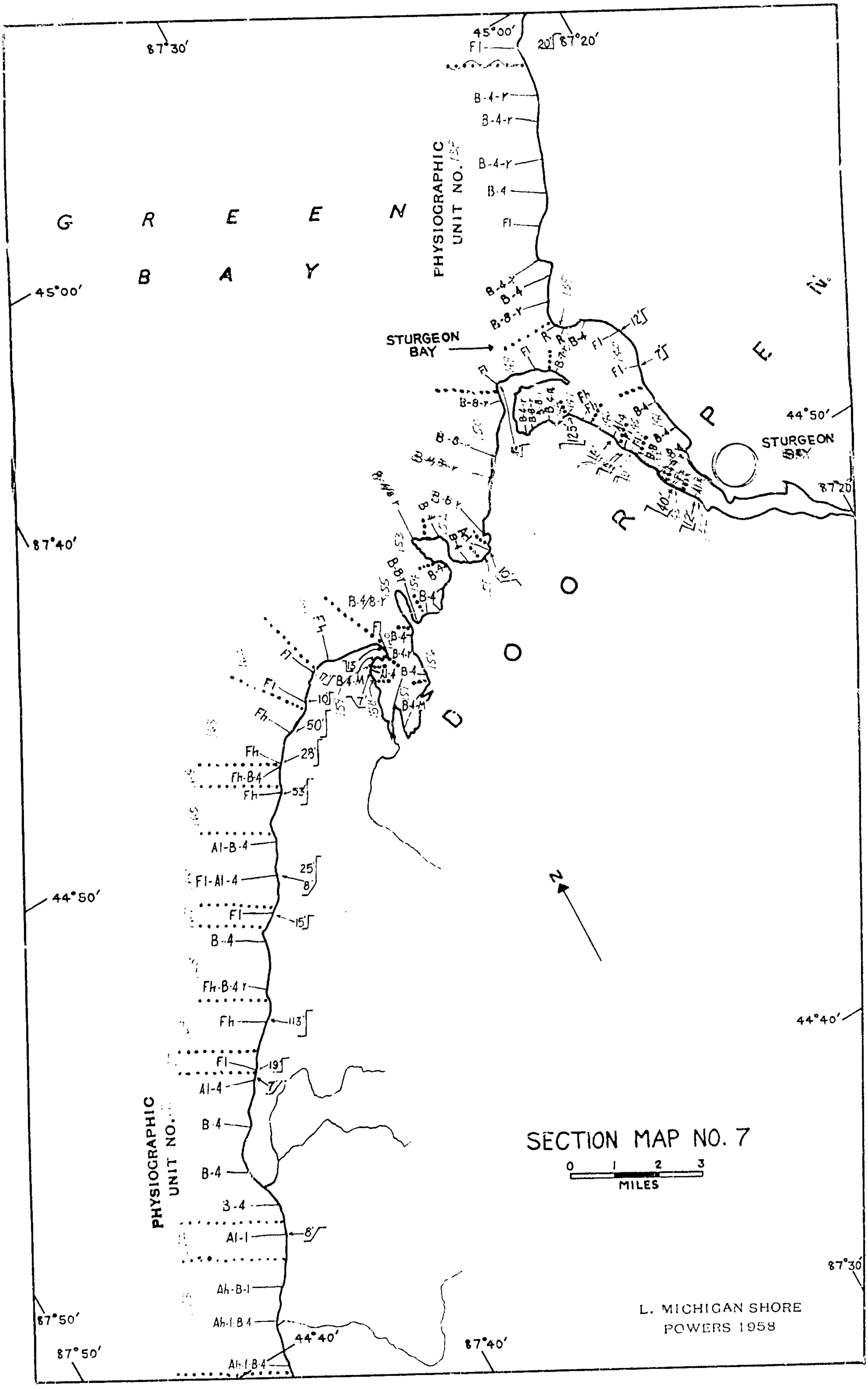

SECTION MAP NO. 3
0 1 2 3
MILES
N
87°50'
44°00'
43°50'
43°40'
87°40'
PHYSIOGRAPHIC UNIT NO. 39
PHYSIOGRAPHIC UNIT NO.
SHEBOYGAN
SHEBOYGAN R.
LAKE MICHIGAN
Ah-4/1
Ah-5/4
Ah-5/1
Ah-4
Ah-1
Ah-5-B-4
Ah-1/4/1
Ah-1/4/5/1
Ah-1/5
Ah-5/1/5/1
Ah-4/5
Ah-5/1/5
Ah-4/1/5
Ah-5
R
B-4
Al-4
Al-5
Dl-C
Dl-Cb
B-4-Cb
L. MICHIGAN SHORE
POWERS 1958

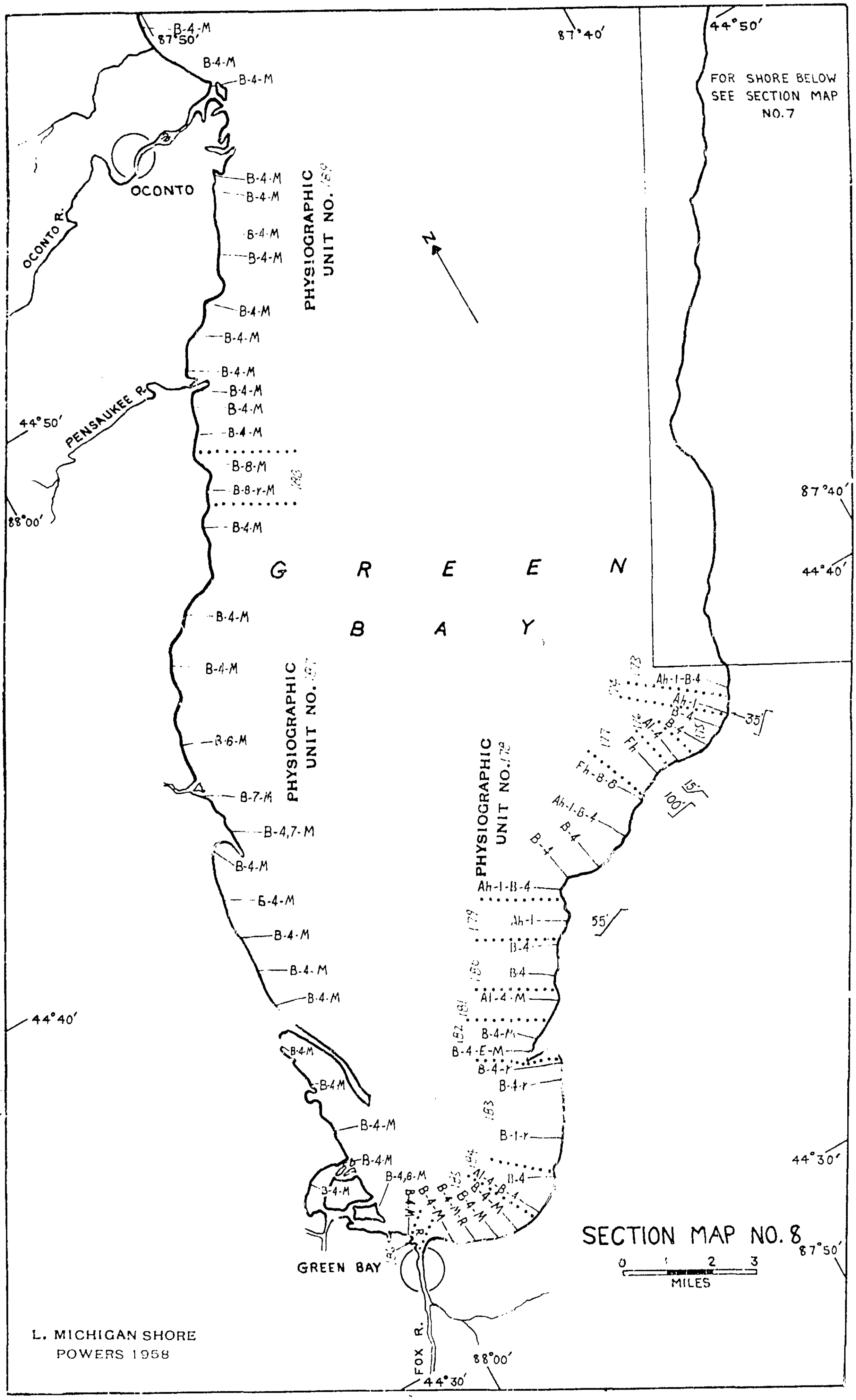


SECTION MAP NO. 4
0 1 2 3
MILES
N
87°40'
87°30'
44°20'
44°10'
KEWAUNEE R.
KEWAUNEE
EAST TWIN R.
WEST TWIN R.
MANITOWOC R.
MANITOWOC
PHYSIOGRAPHIC UNIT NO. 52
PHYSIOGRAPHIC UNIT NO. 45
LAKE MICHIGAN
Ah-1
Ah-1/4
Ah-1/4/1
B-4
Ah-1/4/Al-4
Ah 1/5/1
Ah-1/5/1
Ah-1/5
Ah-1/4/5
Al-4
Ah-1/5/4
Al-1
Al-4/1
Dlb
Dlb/B-4
Dl/B-4
Dl-C
Dl-Cb
B-4-Cb
Al-M
Al-5
Ah-1-Al-5
Al-1-B-4-R
Ah-4
Ah-5/4
Ah-4/5/1
Ah-4/1/4/1
L. MICHIGAN SHORE
POWERS 1958

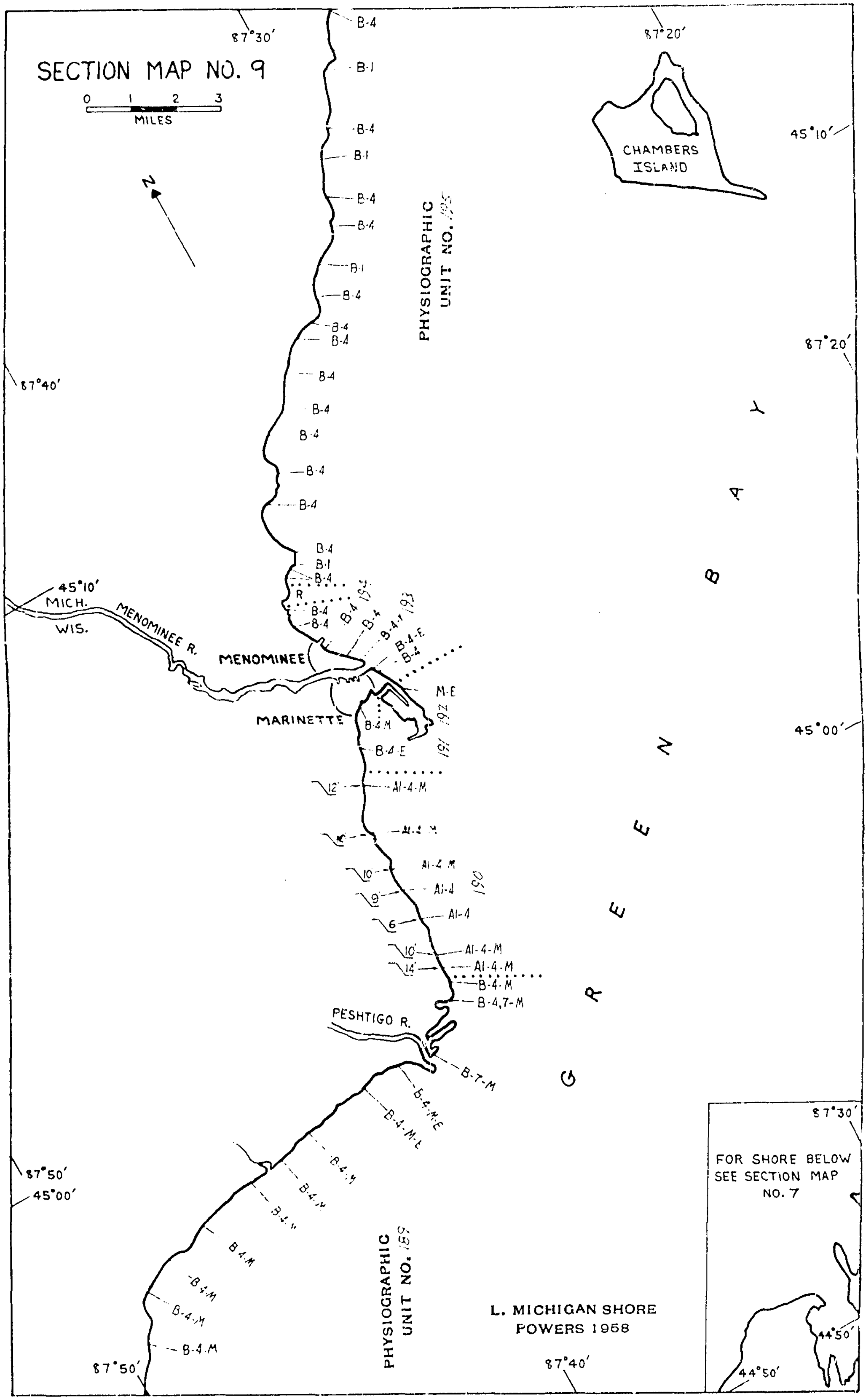

SECTION MAP NO. 5
0 1 2 3
MILES
N
STURGEON BAY
STURGEON BAY
AHNAPEE R.
ALGOMA
LAKE MICHIGAN
PHYSIOGRAPHIC UNIT NO.
PHYSIOGRAPHIC UNIT NO.
87°30′
87°20′
87°10′
44°50′
44°40′
L. MICHIGAN SHORE
POWERS 1958

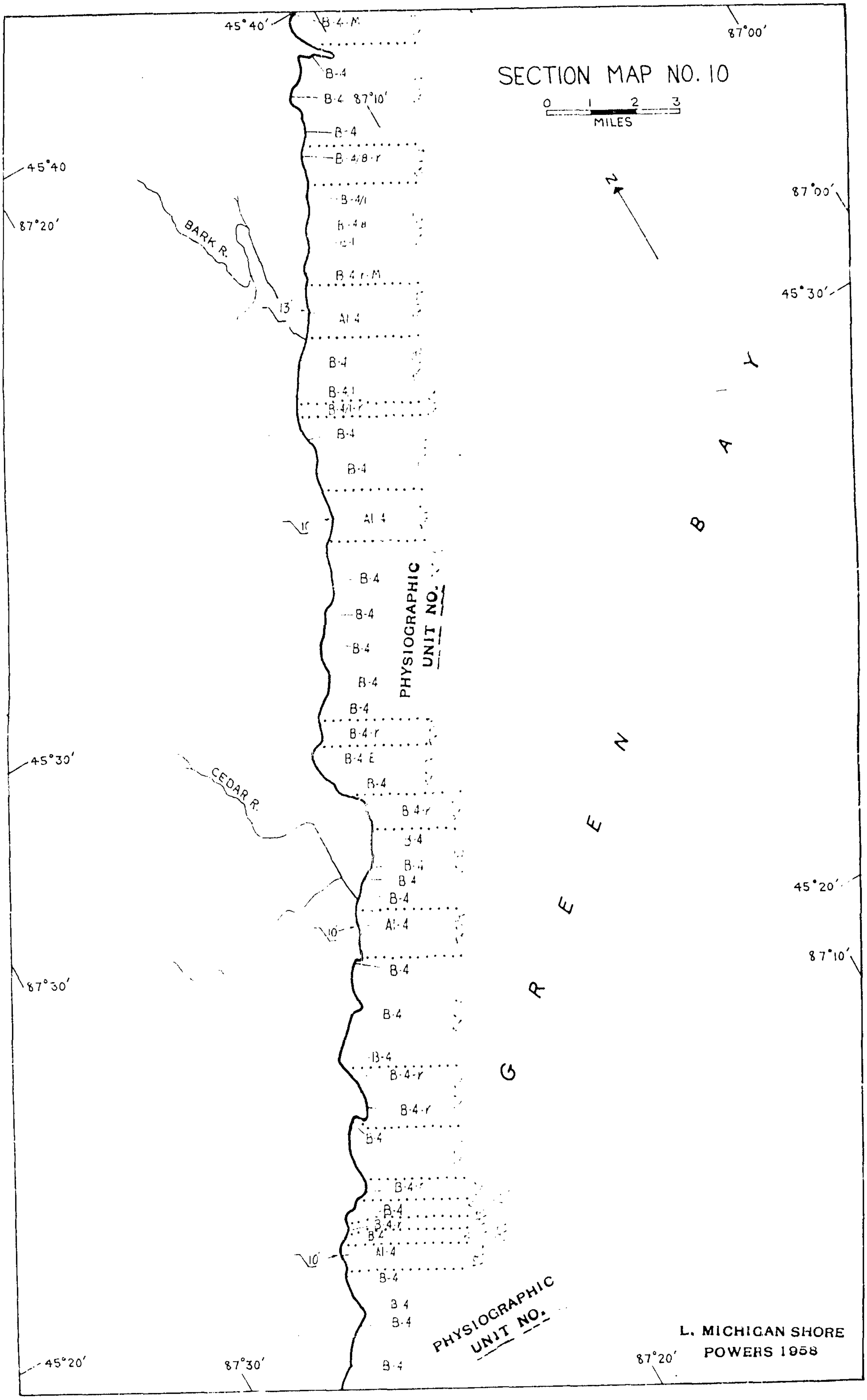

SECTION MAP NO. 6
0 1 2 3
MILES
PHYSIOGRAPHIC UNIT NO. 110
PHYSIOGRAPHIC UNIT NO. 131
PHYSIOGRAPHIC UNIT NO.
GREEN BAY
LAKE MICHIGAN
DOOR PEN.
N
87°00'
45°20'
87°10'
45°10'
87°20'
45°00'
L. MICHIGAN SHORE
POWERS 1958


GREEN BAY
PHYSIOGRAPHIC UNIT NO.
STURGEON BAY
STURGEON BAY
DOOR PEN.
SECTION MAP NO. 7
0 1 2 3
MILES
L. MICHIGAN SHORE
POWERS 1958
87°30′
45°00′
87°20′
45°00′
44°50′
87°40′
87°20′
44°50′
44°40′
87°30′
87°50′
87°50′
44°40′
87°40′

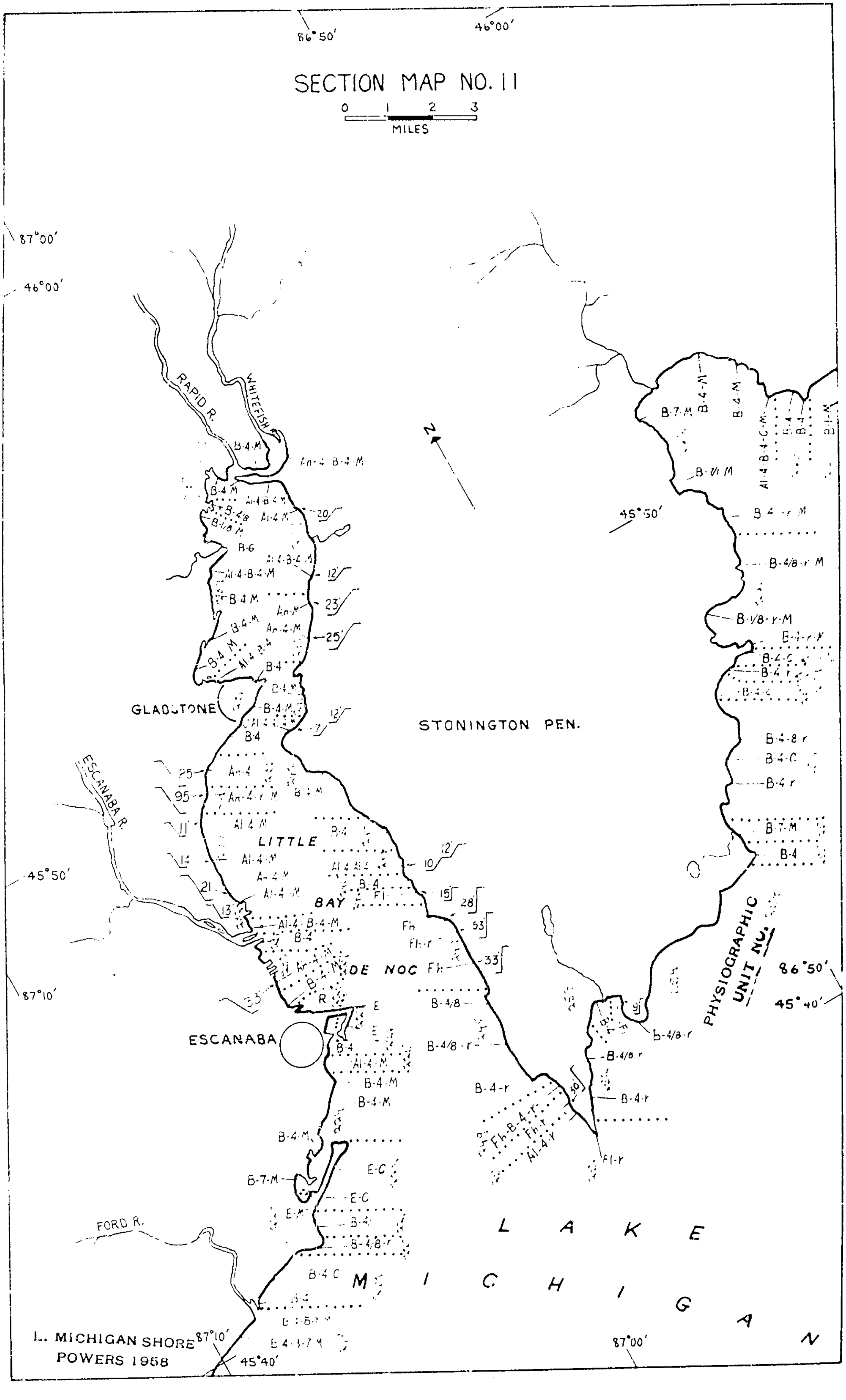


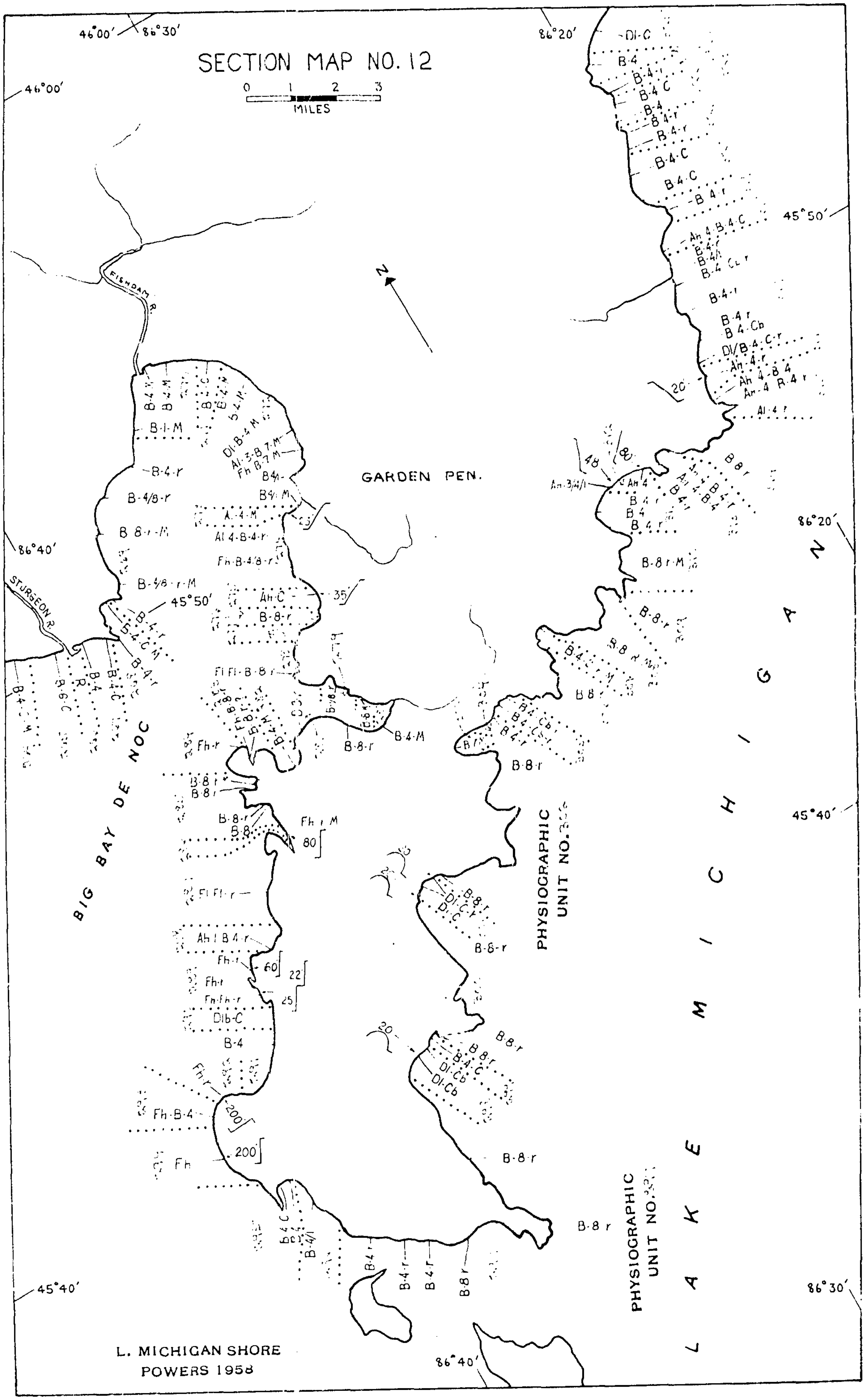
FOR SHORE BELOW SEE SECTION MAP NO.7
OCONTO
OCONTO R.
PENSAUKEE R.
PHYSIOGRAPHIC UNIT NO.
GREEN BAY
GREEN BAY
FOX R.
SECTION MAP NO. 8
MILES
0 1 2 3
L. MICHIGAN SHORE
POWERS 1958
87°50′
87°40′
44°50′
44°40′
44°30′
88°00′
B-4-M
B-8-M
B-8-r-M
B-6-M
B-7-M
B-4,7-M
B-4,6-M
Ah-1-B-4
Ah-1
Fh-B-8
Al-4-M
B-4-E-M
B-4-r
B-1-r
Al-4-B-4
B-4-M-R
35′
15′
100′
55′

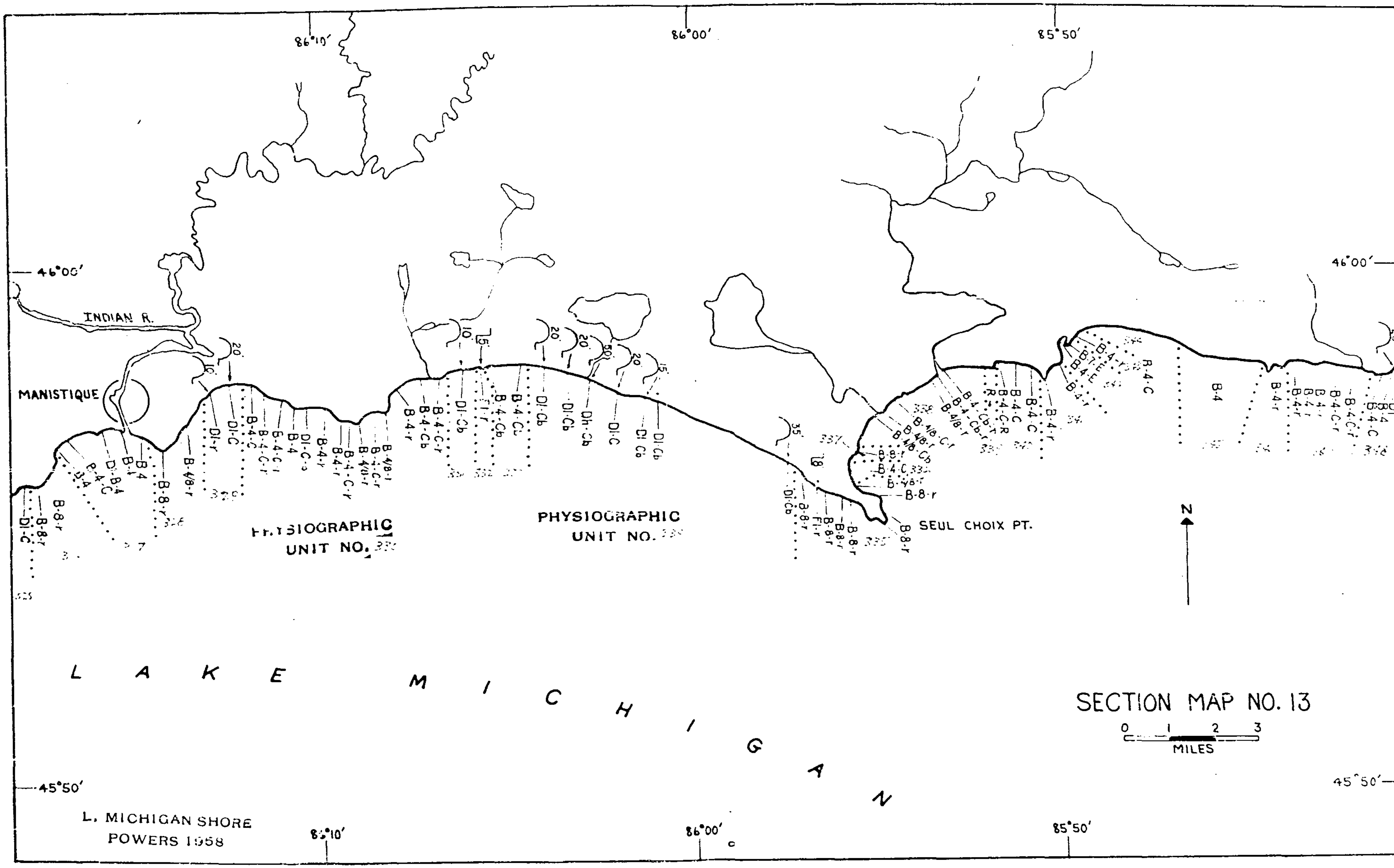

SECTION MAP NO. 9
0 1 2 3
MILES
N
CHAMBERS ISLAND
87°30'
87°20'
45°10'
87°40'
87°50'
45°00'
44°50'
MICH.
WIS.
MENOMINEE R.
MENOMINEE
MARINETTE
PESHTIGO R.
GREEN BAY
PHYSIOGRAPHIC UNIT NO. 195
PHYSIOGRAPHIC UNIT NO. 185
B-4
B-1
B-4-E
B-4-M
M-E
A1-4-M
A1-4
B-4,7-M
B-7-M
B-4-M-E
FOR SHORE BELOW SEE SECTION MAP NO. 7
L. MICHIGAN SHORE
POWERS 1958


SECTION MAP NO. 10
0 1 2 3
MILES
N
GREEN BAY
BARK R.
CEDAR R.
PHYSIOGRAPHIC UNIT NO.
45°40′
45°30′
45°20′
87°00′
87°10′
87°20′
87°30′
B-4
B-4-M
B-4-r
B-4-E
Al-4
L. MICHIGAN SHORE
POWERS 1958

SECTION MAP NO. 11

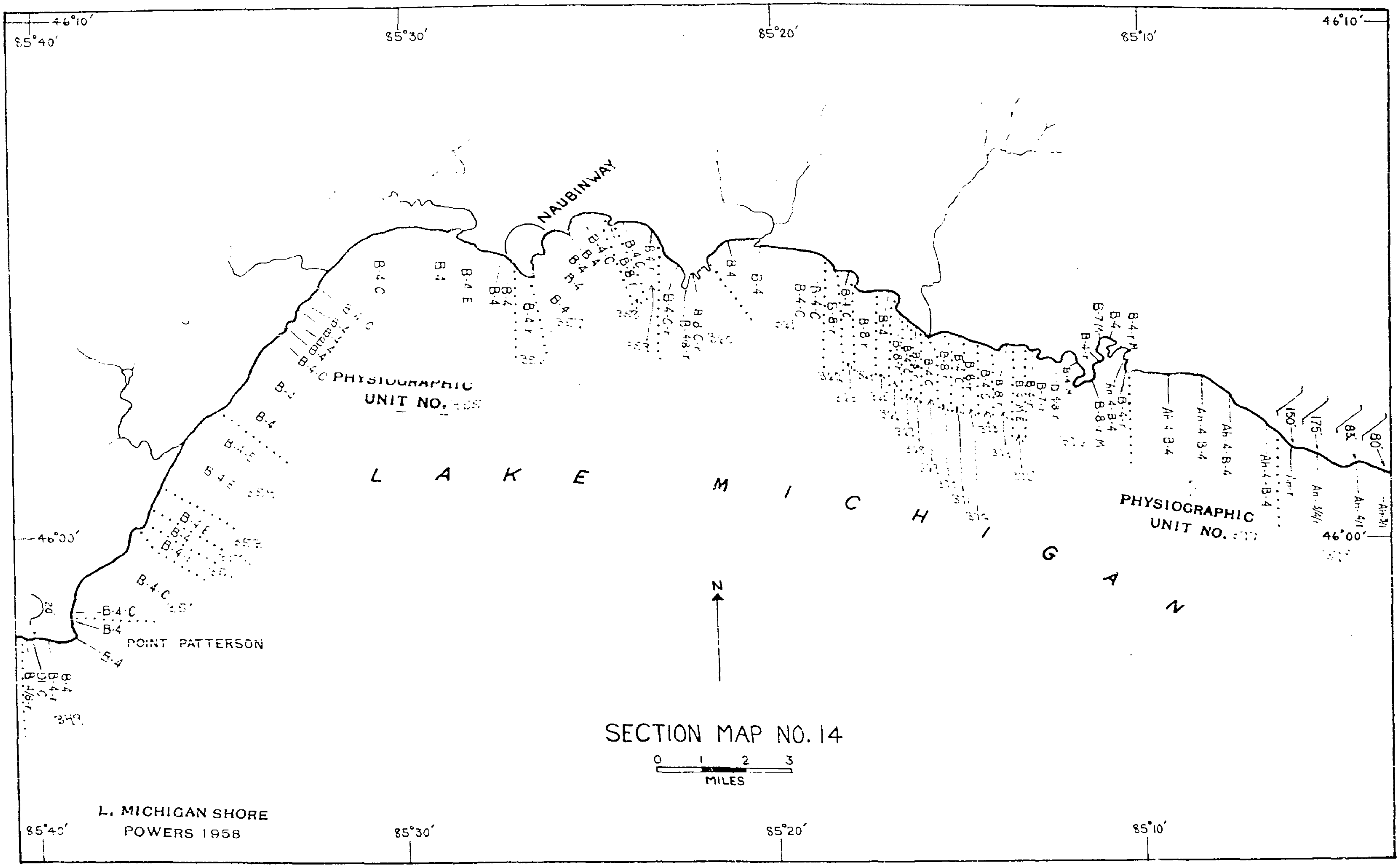


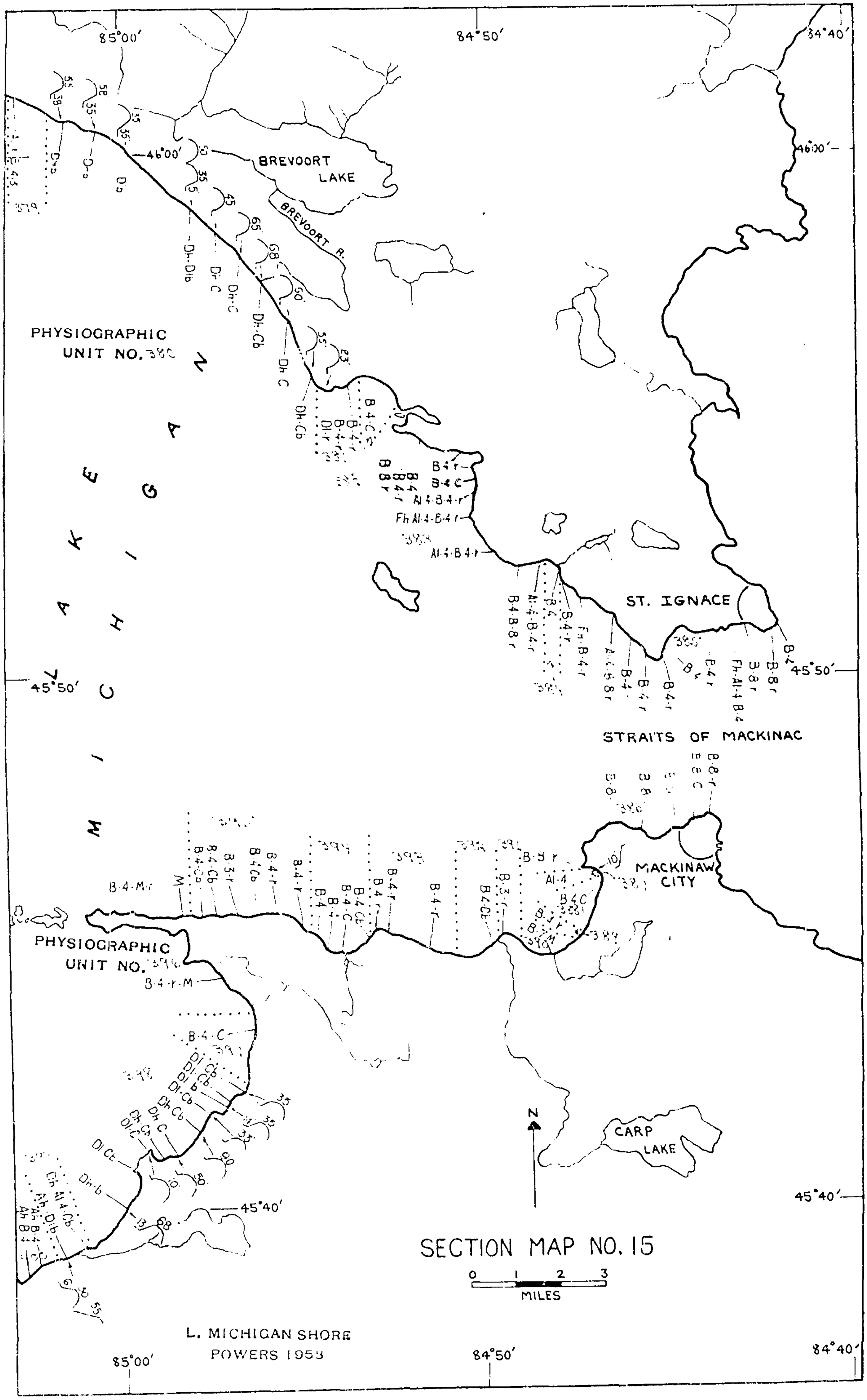

SECTION MAP NO. 12
0 1 2 3
MILES
GARDEN PEN.
BIG BAY DE NOC
LAKE MICHIGAN
PHYSIOGRAPHIC UNIT NO.
FISHDAM R.
STURGEON R.
L. MICHIGAN SHORE
POWERS 1958
46°00'
86°30'
86°20'
45°50'
86°40'
45°40'



SECTION MAP NO. 13

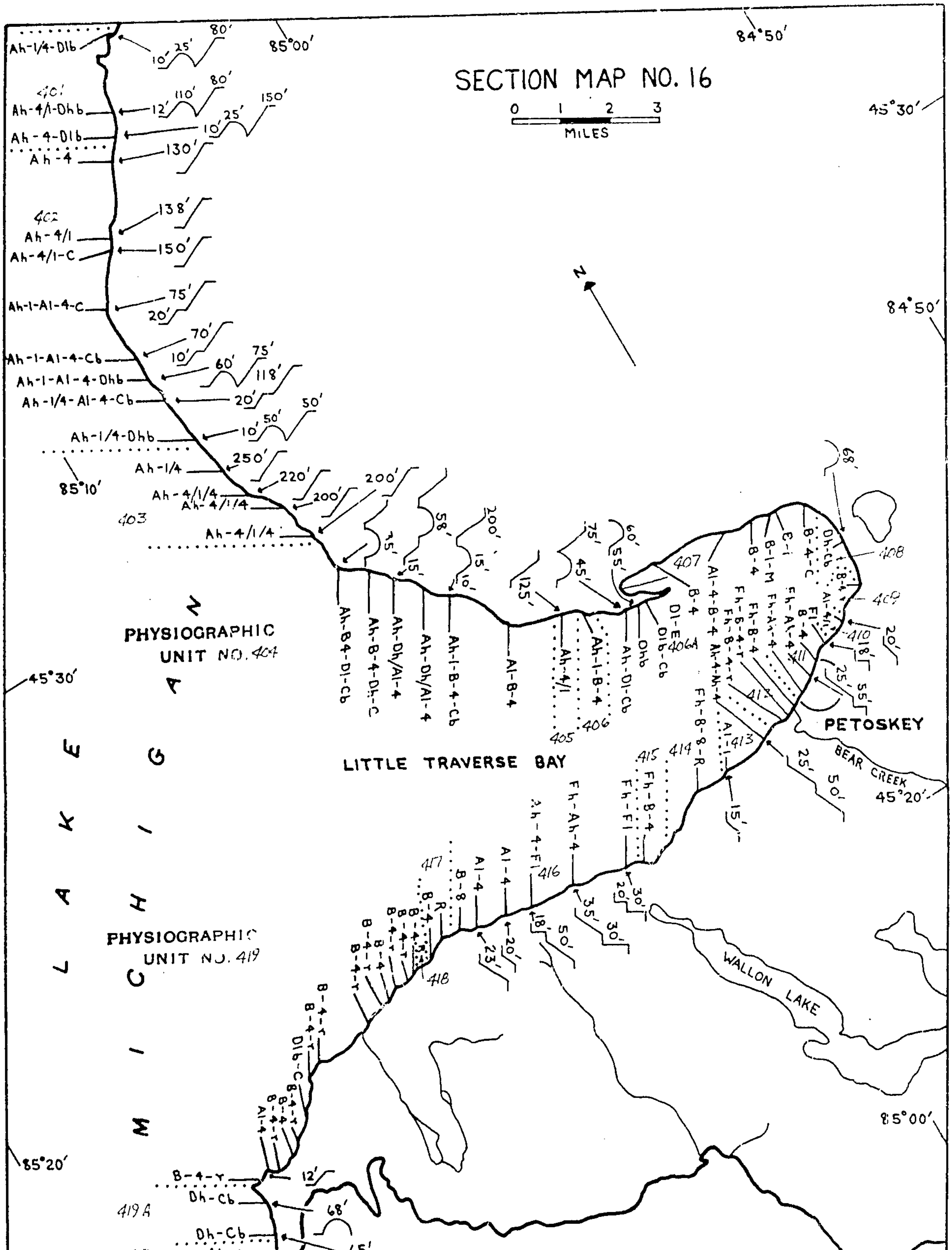
0 1 2 3 MILES

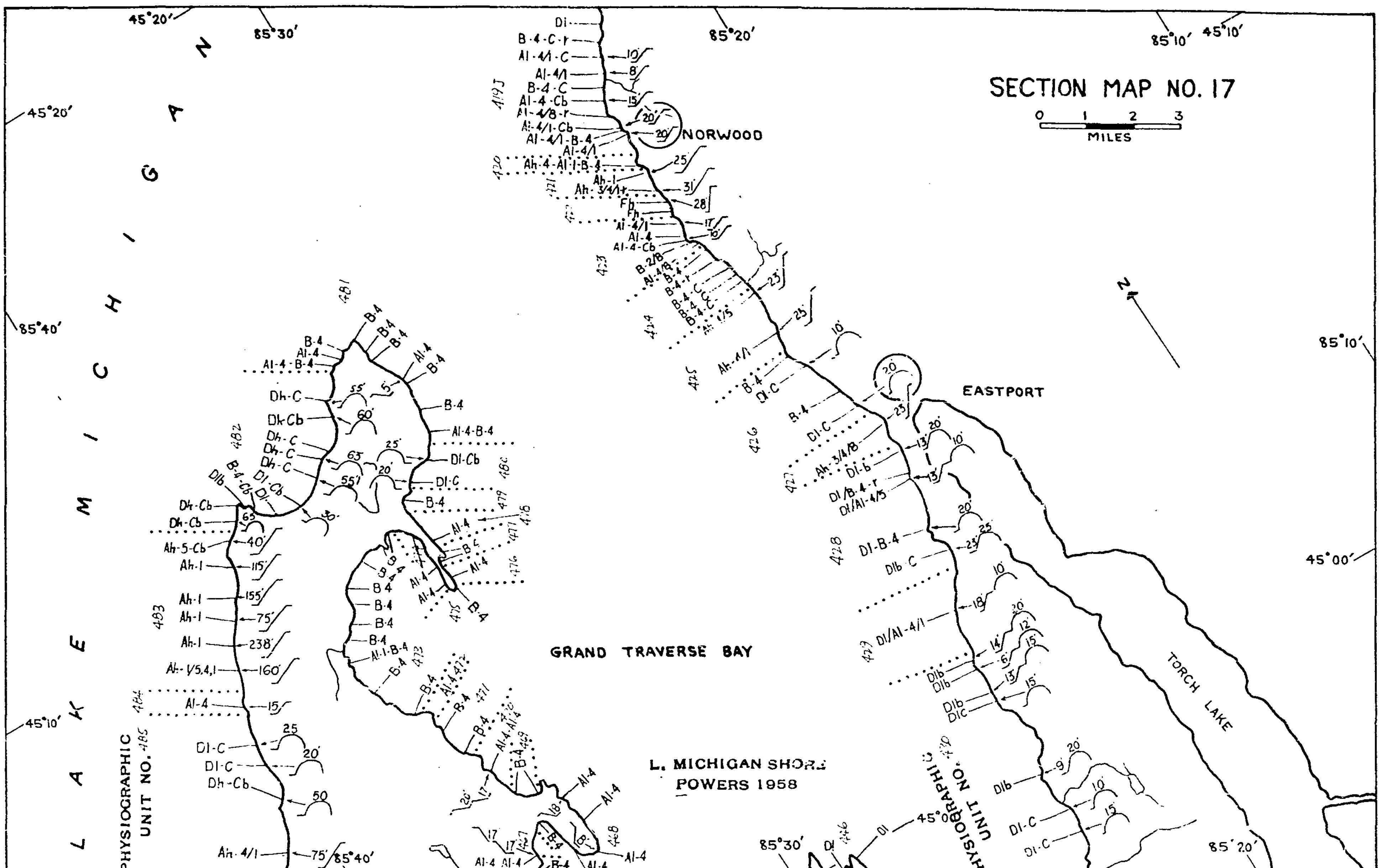

SECTION MAP NO. 14
L. MICHIGAN SHORE
POWERS 1958
LAKE MICHIGAN
NAUBINWAY
POINT PATTERSON
PHYSIOGRAPHIC UNIT NO.
PHYSIOGRAPHIC UNIT NO.
N
0 1 2 3
MILES
46°10′
46°00′
85°40′
85°30′
85°20′
85°10′



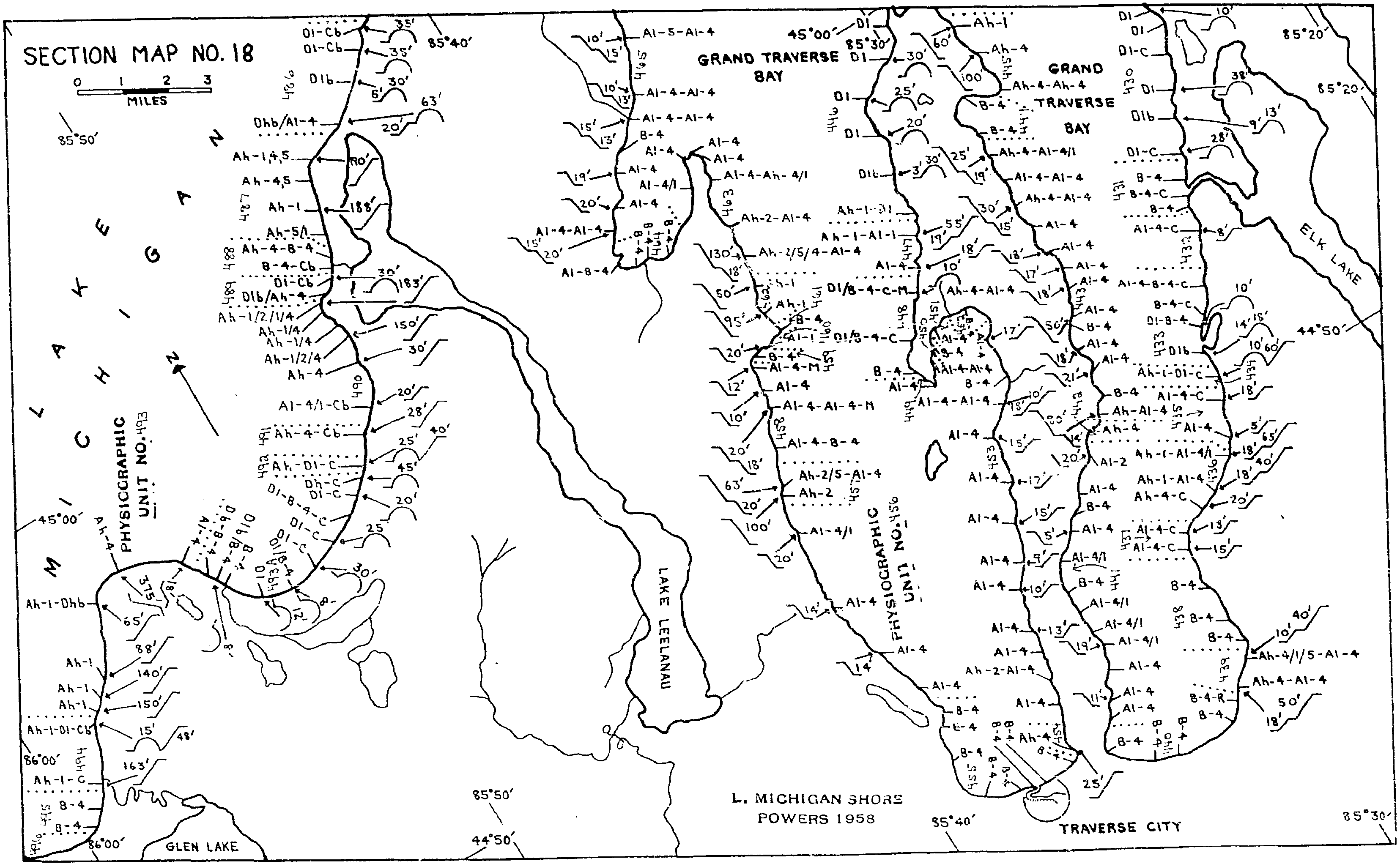
SECTION MAP NO. 15

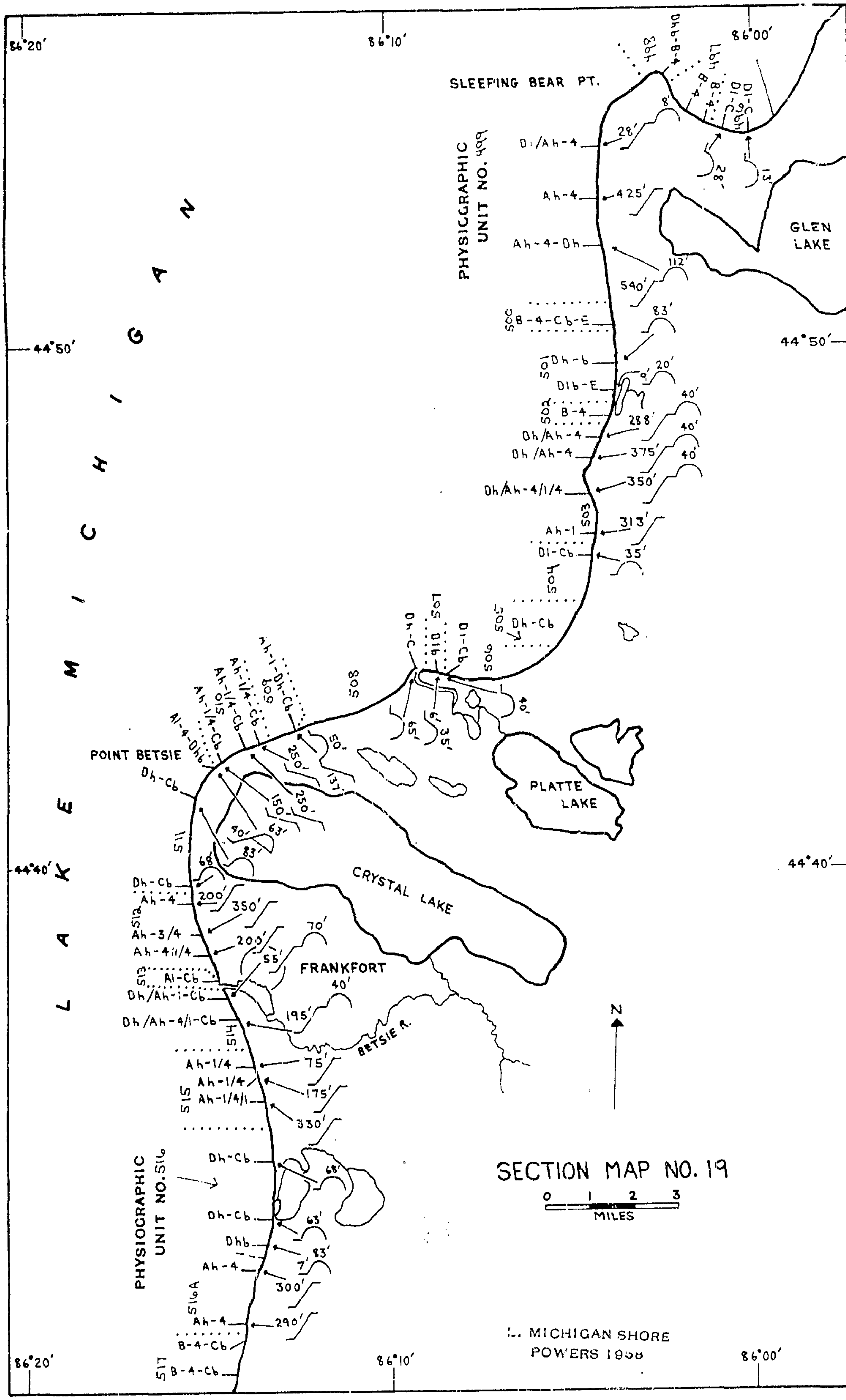
L. MICHIGAN SHORE
POWERS 1953


SECTION MAP NO. 16
0 1 2 3
MILES
N
PHYSIOGRAPHIC UNIT NO. 404
PHYSIOGRAPHIC UNIT NO. 419
LAKE MICHIGAN
LITTLE TRAVERSE BAY
PETOSKEY
BEAR CREEK
WALLON LAKE
LAKE CHARLEVOIX
CHARLEVOIX
85°00'
84°50'
45°30'
85°10'
45°20'
85°20'
L. MICHIGAN SHORE
POWERS 1958

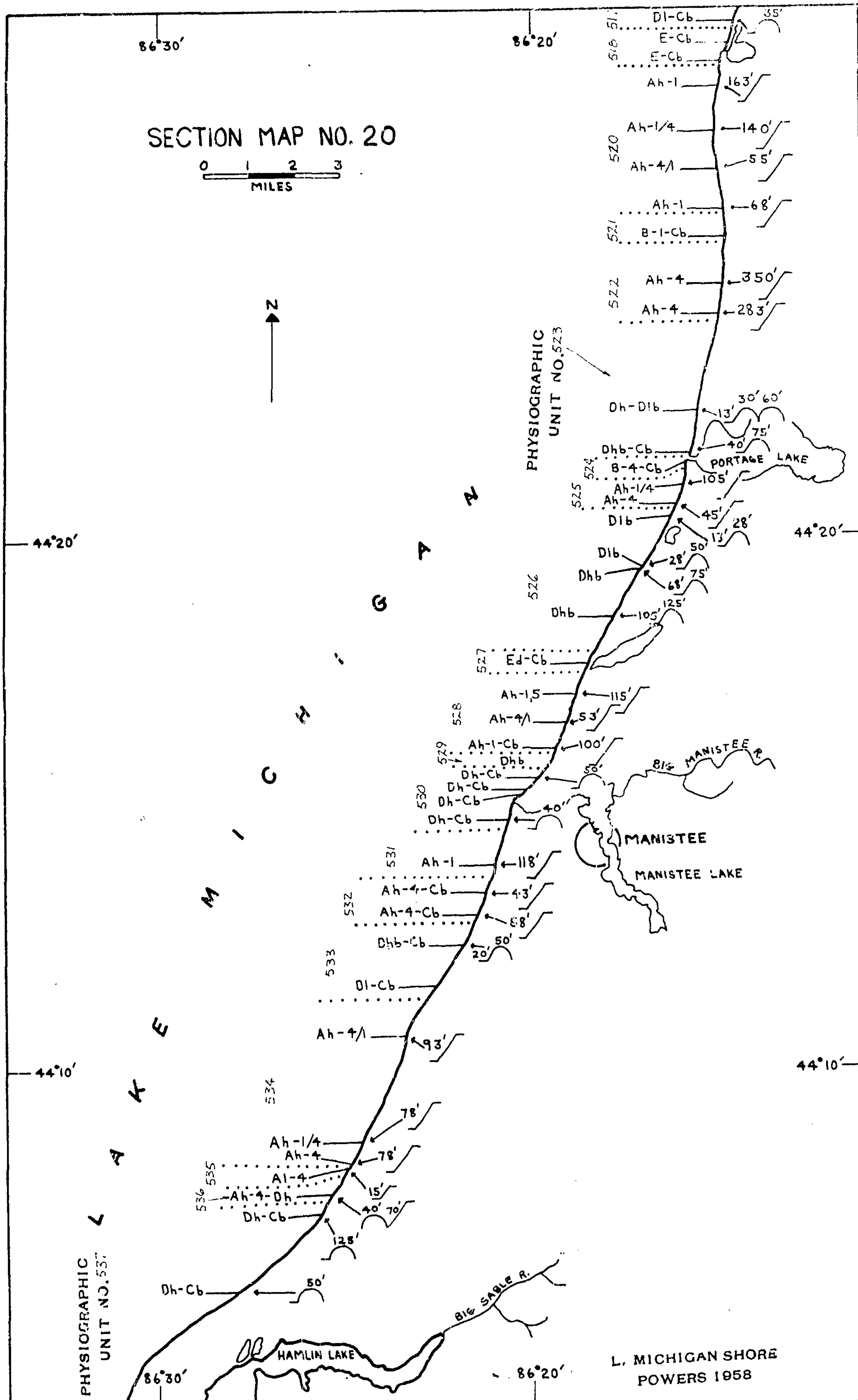


SECTION MAP NO. 17
0 1 2 3
MILES
NORWOOD
EASTPORT
TORCH LAKE
GRAND TRAVERSE BAY
L. MICHIGAN SHORE
POWERS 1958
LAKE MICHIGAN
PHYSIOGRAPHIC UNIT NO. 485
PHYSIOGRAPHIC UNIT NO. 430
N
45°20′
85°30′
85°20′
85°10′
45°10′
85°40′
45°00′
85°20′

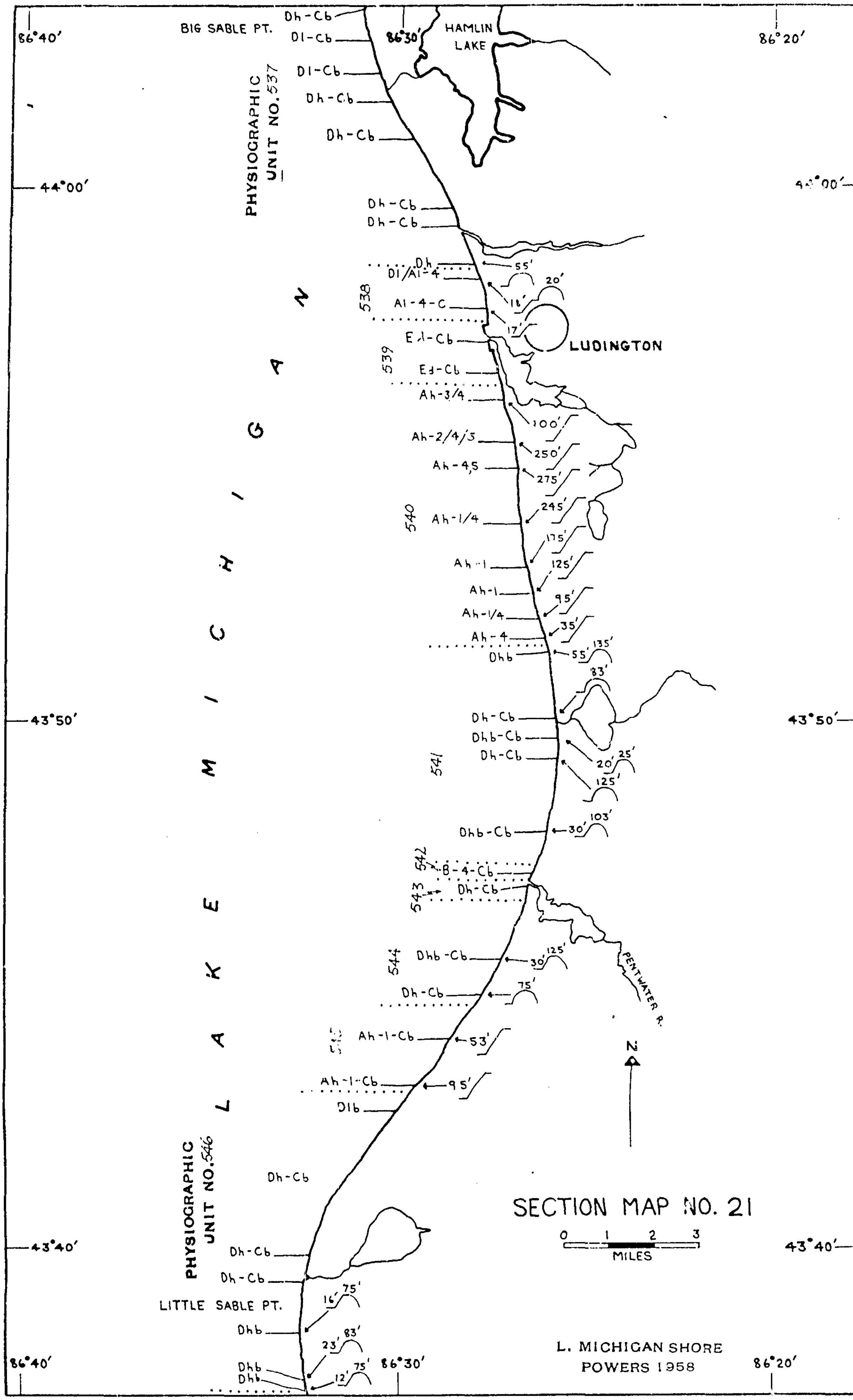

SECTION MAP NO. 18
0 1 2 3
MILES
LAKE MICHIGAN
PHYSIOGRAPHIC UNIT NO. 493
PHYSIOGRAPHIC UNIT NO. 456
GRAND TRAVERSE BAY
LAKE LEELANAU
ELK LAKE
GLEN LAKE
TRAVERSE CITY
L. MICHIGAN SHORE
POWERS 1958



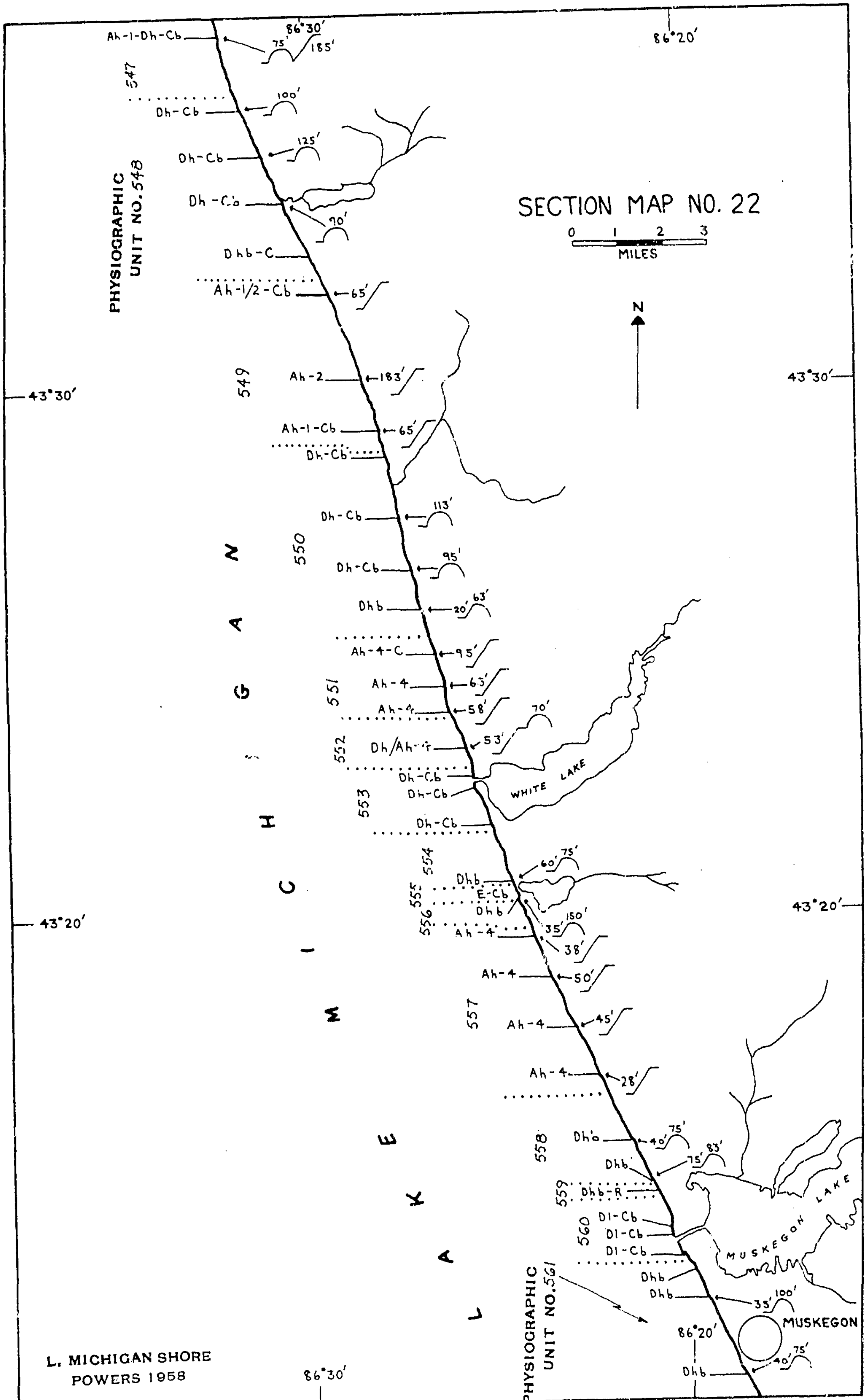
SECTION MAP NO. 19
0 1 2 3
MILES
L. MICHIGAN SHORE
POWERS 1958
LAKE MICHIGAN
SLEEPING BEAR PT.
PHYSIOGRAPHIC UNIT NO. 499
PHYSIOGRAPHIC UNIT NO. 516
GLEN LAKE
PLATTE LAKE
CRYSTAL LAKE
POINT BETSIE
FRANKFORT
BETSIE R.
N
86°20'
86°10'
86°00'
44°50'
44°40'

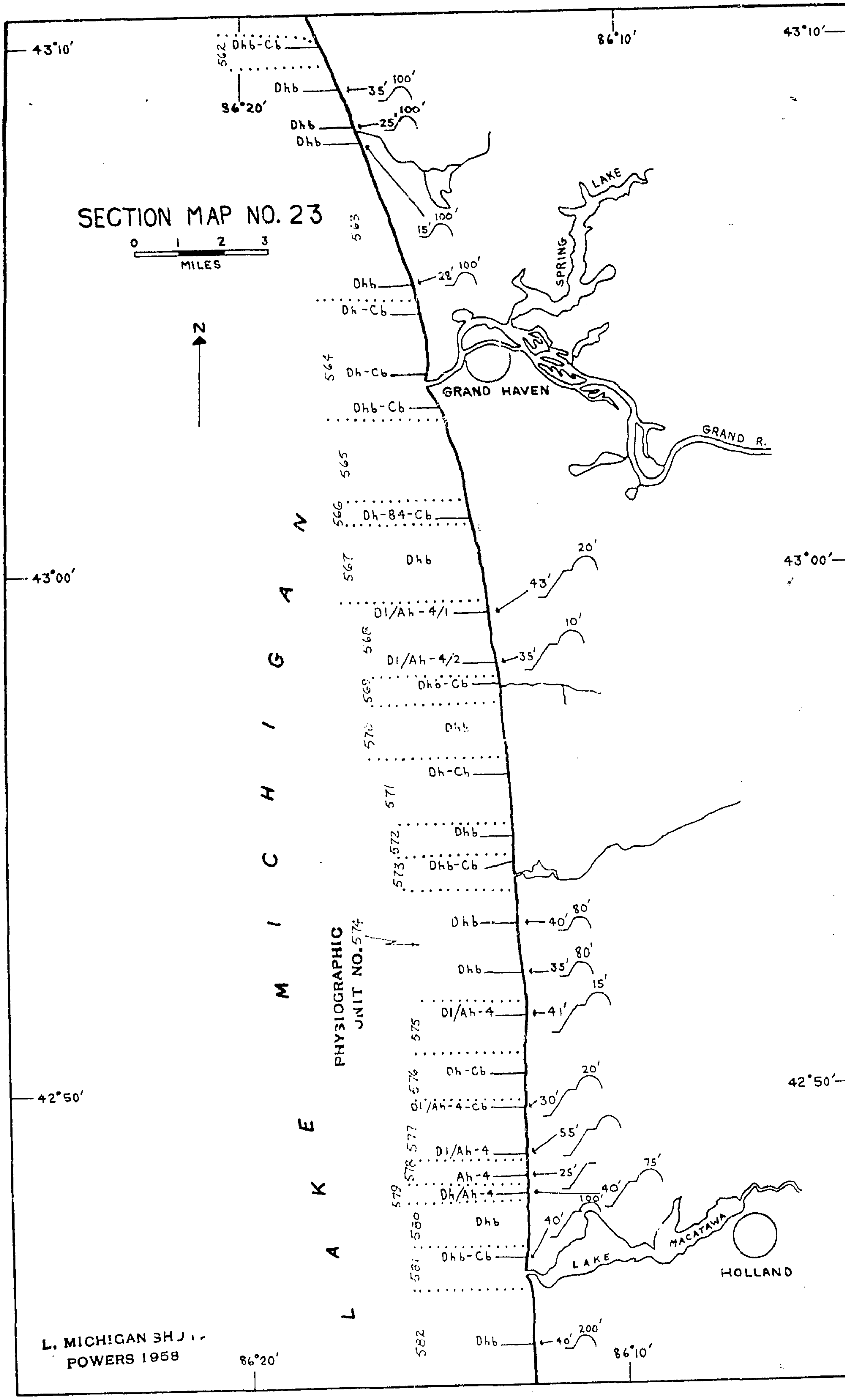


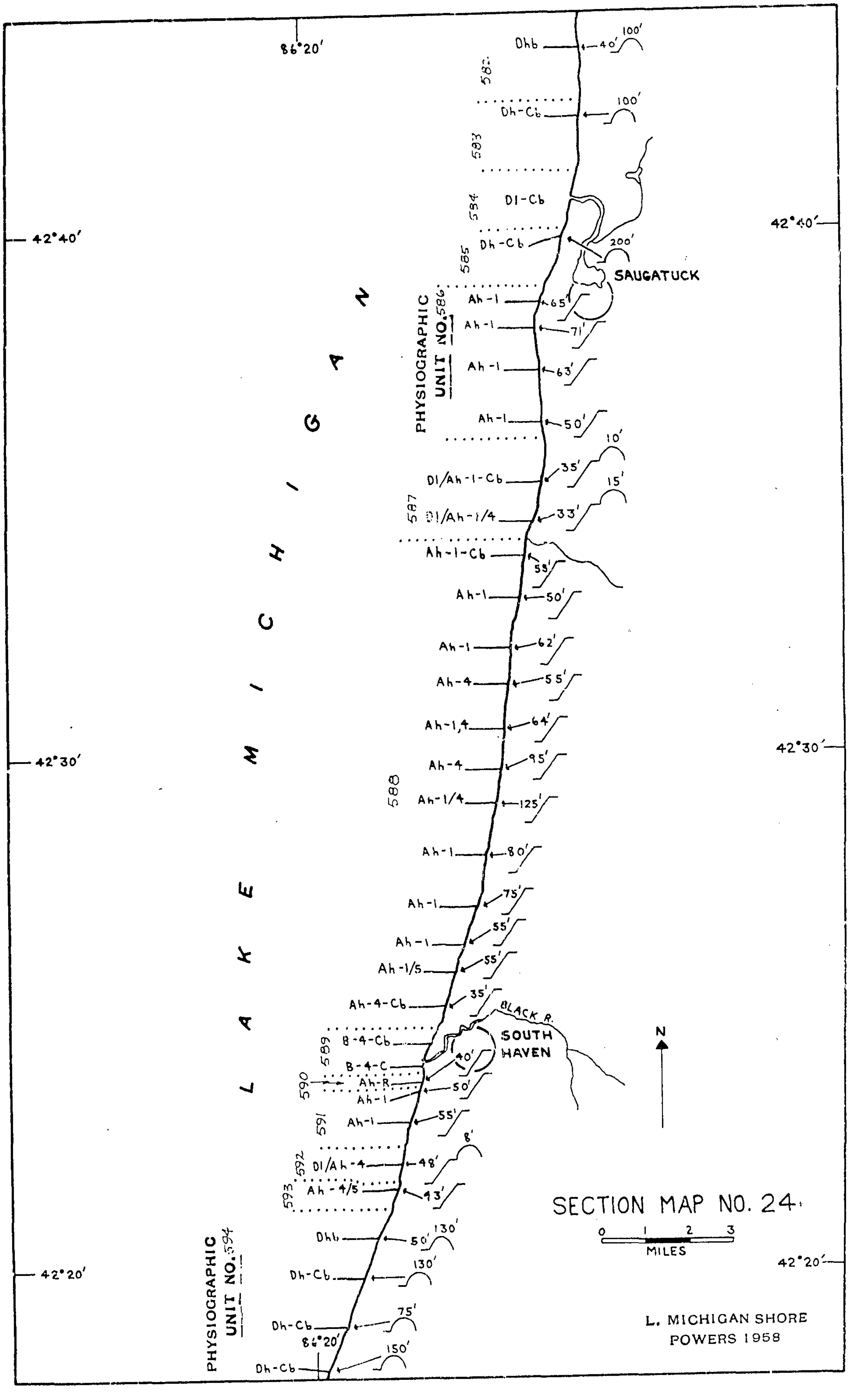
SECTION MAP NO. 20
0 1 2 3
MILES
N
LAKE MICHIGAN
PHYSIOGRAPHIC UNIT NO.523
PHYSIOGRAPHIC UNIT NO.537
86°30′
86°20′
44°20′
44°10′
PORTAGE LAKE
BIG MANISTEE R.
MANISTEE
MANISTEE LAKE
BIG SABLE R.
HAMLIN LAKE
Dl-Cb
E-Cb
E-Cb
Ah-1
Ah-1/4
Ah-4/1
Ah-1
B-1-Cb
Ah-4
Ah-4
Dh-Dlb
Dhb-Cb
B-4-Cb
Ah-1/4
Ah-4
Dlb
Dlb
Dhb
Dhb
Ed-Cb
Ah-1,5
Ah-4/1
Ah-1-Cb
Dhb
Dh-Cb
Dh-Cb
Dh-Cb
Dh-Cb
Ah-1
Ah-4-Cb
Ah-4-Cb
Dhb-Cb
Dl-Cb
Ah-4/1
Ah-1/4
Ah-4
Al-4
Ah-4-Dh
Dh-Cb
Dh-Cb
35′
163′
140′
55′
68′
350′
283′
13′
30′
60′
75′
40′
105′
45′
13′
28′
50′
28′
68′
75′
105′
125′
115′
53′
100′
50′
40′
118′
43′
58′
50′
20′
93′
78′
78′
15′
40′
70′
128′
50′
518
520
521
522
524
525
526
527
528
529
530
531
532
533
534
535
536
L. MICHIGAN SHORE
POWERS 1958



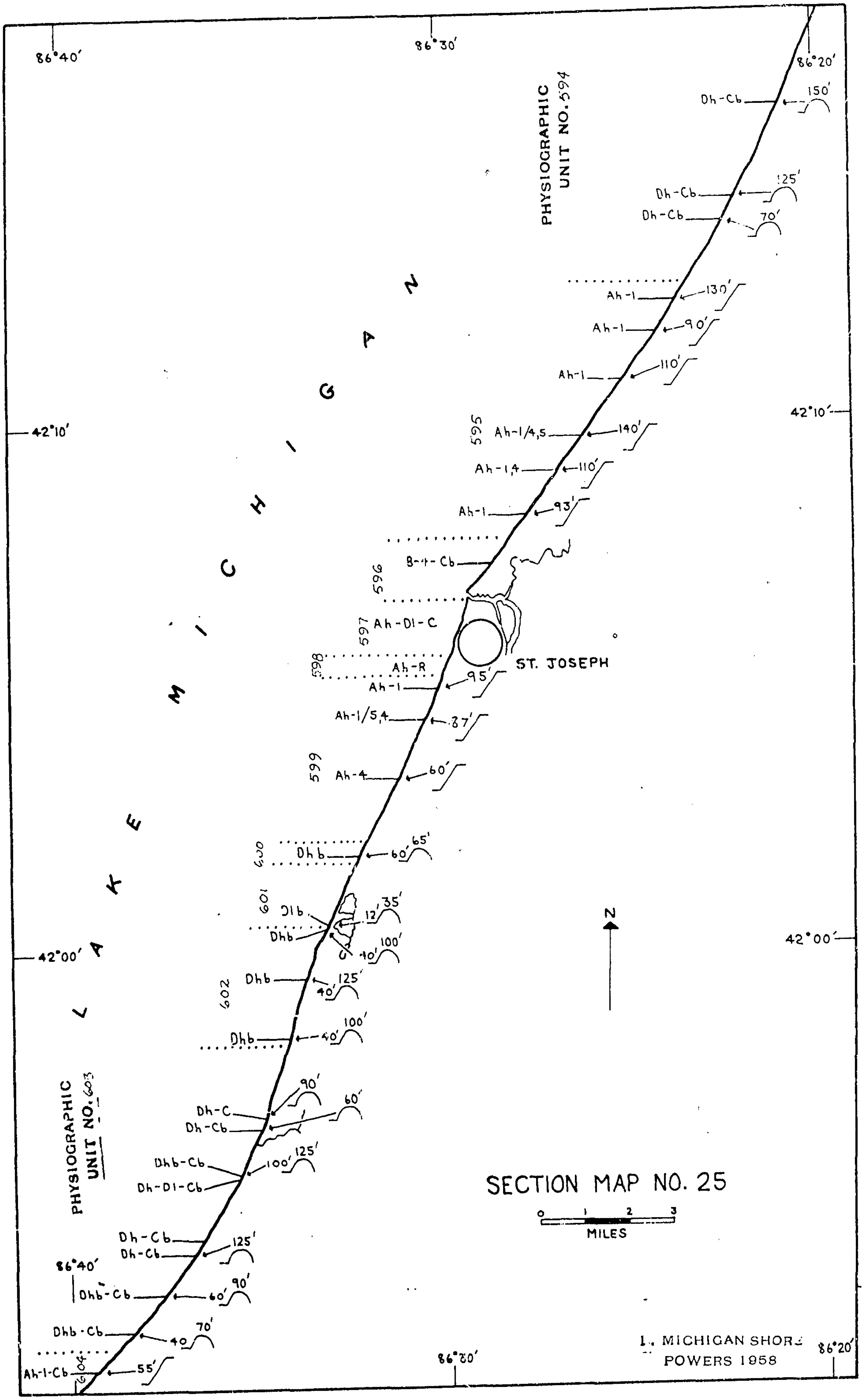
BIG SABLE PT.
HAMLIN LAKE
86°40′
86°30′
86°20′
44°00′
43°50′
43°40′
PHYSIOGRAPHIC UNIT NO. 537
PHYSIOGRAPHIC UNIT NO. 546
LAKE MICHIGAN
LUDINGTON
PENTWATER R.
LITTLE SABLE PT.
N
SECTION MAP NO. 21
0 1 2 3
MILES
L. MICHIGAN SHORE
POWERS 1958

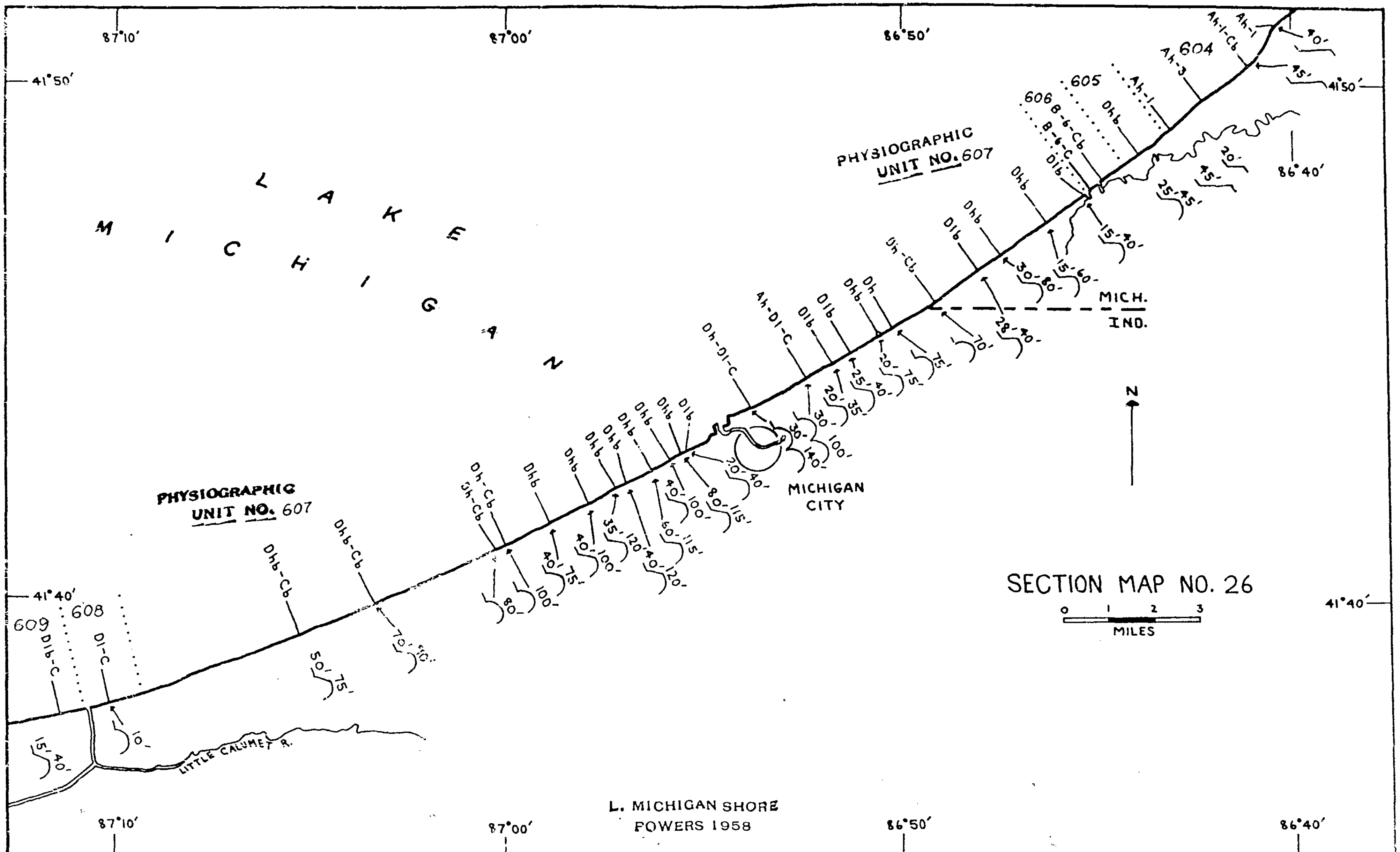

SECTION MAP NO. 22
0 1 2 3
MILES
N
86°30'
86°20'
43°30'
43°20'
PHYSIOGRAPHIC UNIT NO. 548
PHYSIOGRAPHIC UNIT NO. 561
547
549
550
551
552
553
554
555
556
557
558
559
560
LAKE MICHIGAN
WHITE LAKE
MUSKEGON LAKE
MUSKEGON
Ah-1-Dh-Cb
Dh-Cb
Dhb-C
Ah-1/2-Cb
Ah-2
Ah-1-Cb
Ah-4-C
Ah-4
Dh/Ah
Dhb
E-Cb
Dhb-R
Dl-Cb
75'
185'
100'
125'
90'
65'
183'
113'
95'
20'
63'
58'
70'
53'
60'
150'
35'
38'
50'
45'
28'
40'
83'
33'
L. MICHIGAN SHORE
POWERS 1958


SECTION MAP NO. 23
0 1 2 3
MILES
N
LAKE MICHIGAN
PHYSIOGRAPHIC UNIT NO. 574
GRAND HAVEN
SPRING LAKE
GRAND R.
LAKE MACATAWA
HOLLAND
43°10′
43°00′
42°50′
86°20′
86°10′
562 Dhb-Cb
Dhb
35′ 100′
25′ 100′
15′ 100′
563
28′ 100′
Dh-Cb
564
Dhb-Cb
565
566 Dh-B4-Cb
567 Dhb
Dl/Ah-4/1
43′ 20′
568
Dl/Ah-4/2
35′ 10′
569 Dhb-Cb
570 Dhb
Dh-Cb
571
572 Dhb
573 Dhb-Cb
40′ 80′
35′ 80′
Dl/Ah-4
41′ 15′
575
576 Dh-Cb
Dl/Ah-4-Cb
30′ 20′
577 Dl/Ah-4
55′
578 Ah-4
25′ 75′
579 Dh/Ah-4
40′ 100′
580 Dhb
40′
581 Dhb-Cb
582 Dhb
40′ 200′
L. MICHIGAN SHJ
POWERS 1958



SECTION MAP NO. 24


86°40′
86°30′
86°20′
42°10′
42°00′
PHYSIOGRAPHIC UNIT NO. 594
PHYSIOGRAPHIC UNIT NO. 603
LAKE MICHIGAN
ST. JOSEPH
N
SECTION MAP NO. 25
0 1 2 3
MILES
L. MICHIGAN SHORE
POWERS 1958
Dh-Cb
Ah-1
Ah-1/4,5
Ah-1,4
B-4-Cb
Ah-DI-C
Ah-R
Ah-1/5,4
Ah-4
Dhb
Dh-C
Dhb-Cb
Dh-DI-Cb
Ah-1-Cb
595
596
597
598
599
600
601
602
604



Best Available Copy